BENEATH THE BOTTOM LINE: AGRICULTURAL APPROACHES TO REDUCE AGRICHEMICAL CONTAMINATION OF GROUNDWATER

Volume II--Contract Papers

Part F: Research and Education

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SYSTEMS APPROACHES IN AGRICULTURAL RESEARCH: APPLICATIONS FOR GROUNDWATER PROTECTION

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SYSTEMS APPROACHES IN AGRICULTURAL RESEARCH: APPLICATIONS FOR GROUNDWATER PROTECTION

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ABSTRACT. Complex problems often require the attention of interdisciplinary teams - groundwater protection is such a problem. Since World War II, methods have been developed to study complex systems. These methods evolved into two different directions: soft systems methodologies and operations research. These methods in addition to new knowledge-based systems techniques can enhance interdisciplinary research. The divergence of "soft" systems from operations research has taken place recently (since the early 1970s). A specific seven stage method is presented and put into the context of a farming system. Interestingly, no references to soft system methodology applications in agriculture were found. An argument for this is proposed.

"Hard" system methodologies such as modeling, simulation, and optimization, on the other hand, are so pervasive through the agricultural sciences that no attempt was made to catalog them. Comprehensive, summaries of the state-of-the-art were attempted as recently as 1982; however, it would be nearly impossible now. These readily adopted technologies are reviewed briefly in the context of supporting interdisciplinary teams.

Knowledge-based system techniques have arrived rather recently. Their integration with "hard" and "soft" system methods promise a robust hybrid of existing methods. The results of a recent conference on the potential of such technologies are presented .

Finally, the author's perceived obstacles - professional, technological, and institutional - are presented in addition to some potential policies that may reduce the effects of those obstacles.

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INTRODUCTION

Traditional agricultural systems in the United States have encountered tremendous changes in technology over the past 50 years. Driving those technical innovations have been changes in farming philosophy. Maximizing production and maximizing profits have been predominant philosophies for agriculture. The factors that were incorporated into these decisions had a relatively short horizon - normally that of the production year. Long-term effects such as loss of topsoil through erosion, contamination of surfacewater and groundwater, and the reduction of biological diversity were not considered in most farming decisions. It is very difficult for a producer to attach an economic value to these factors. As our nation's sensitivity to contamination of natural resources increases, land grant institutions and government agencies have reacted by developing methodologies for helping producers maximize farm profits while minimizing negative environmental impacts.

A common component of many of these methodologies is information. Sensor technologies are being developed to generate information for computer use. Simulation models are being developed to predict responses of complex systems. Artificial intelligence techniques and numerical optimization methods are being developed to use the data generated from sensors, simulations and historic data bases to support, enhance and even automate human decisions.

This paper will examine systematic approaches to dealing with this information, using the farming system as an example. As a component of a greater whole, the farming system receives inputs from its environment and feeds outputs back to it. Traditionally, the primary inputs considered were economic inputs such as fertilizer, pest control chemicals, seed, market requirements and government program guidelines. In the broader sense, however, the system must respond to factors such as socio-political inputs, long-lasting effects on the environment and export market influences. Also, outputs such as waste products, transported soil, and transported agrichemicals must be considered in addition to traditional outputs such as agricultural produce.

This paper reviews potential methodologies that enable scientists, as well as policy makers, to study this complex system. A review of current "soft" systems techniques is presented with application toward studying the farm as a part of a greater system. Traditional "hard" systems approaches are reviewed. Finally, the contribution of knowledge-based technologies to support interdisciplinary research and cooperation for intelligent decision making about the management of production and environmental systems will be presented.

AGRICULTURAL SYSTEMS

A system may be defined as a set of elements which are related to each other in some way to form a whole (Checkland, 1981). This whole demonstrates properties which are more than simply a aggregation of the properties of the individual elements. For example, a class of students is a system. The class has a unique personality which is a function of the personalities of individual students, but is much more than just a sum of those personalities. The system is made up of relationships between the students, actors (in this case students and the instructor), the physical environment, and even the topic being studied. Although the classroom is a small, well-constrained example, it is a very complex system. For example, if you were introduced to each of the students individually, would it be possible to predict all of the unique properties of the class as a whole? Probably not. As you can see from this example, the farming system and its interactions with outside factors such as the environment is an extremely complex system.

The traditional scientific approach to dealing with complex physical and social systems has been to reduce the system into elements which can be dealt with individually. An excellent history of scientific thought can be found in Checkland (1981). These individual elements are treated as if they were isolated from interactions with other elements of the system. Elements of a system can normally be described in differing levels of complexity.

Each level of complexity demonstrates unique properties which lower levels - elements reduced even further - do not. In this manner, we can describe most systems as hierarchical arrangements of sub-systems. This concept is the basic substrate of the "systems approach". It is the study of the whole system, including its subsystems and interactions between those subsystems that will allow managers, policymakers, and scientists to make informed decisions about factors that affect the system as a whole. This concept is stated most eloquently by Checkland (1981):

> Rene Descartes taught Western civilization that the thing to do with complexity was to break it up into component parts and tackle them separately. The lesson has been well learned, and the idea is deeply embodied not only in scientists, for whom the idea is central, but in anyone who has a Western-style education. Systems thinking, however, starts from noticing the unquestioned Cartesian assumption: namely, that a component part is the same when separated out as it is when part of a whole. This makes finding out about systems thinking very different from finding out about, say, Renaissance literature, the politics of the Middle East, or natural selection in the fruit fly. The Cartesian legacy provides us with an unnoticed framework - a set of intellectual pigeon-holes - into which we place the new knowledge we acquire. Systems thinking is different because it is about the framework itself. Systems thinking does not drop into its pigeon-hole, it changes the shape and structure of the whole framework of pigeon-holes.

Attempts at defining the distinguishing features of a "system" have been made in several different disciplines; however, common concepts that run through most definitions are those of emergence, hierarchy, communication, and control (Checkland, 1981; Litterer, 1963; Deutsch, 1963; Beer, 1972). Atkinson and

Checkland (1988) elaborate the set of necessary properties as:

> 1. A boundary exists, separating the system from its environment(s) in a number of ways which may include: spatially, temporally, informationally, and organizationally.
>
> 2. Emergent properties are characteristic of the system as a whole, the result of the combination of parts which constitute the whole.
>
> 3. Parts (subsystems and sub-subsystems) which are themselves systems have the properties listed here, creating a rich inner "environment".
>
> 4. There are several systematic processes which may include the following, which are not mutually exclusive: (a) adapting to negate the effect of environmental changes, (b) transforming matter / energy / information, and (c) steering, in the sense of exhibiting goal-directed behavior (see no. 6).
>
> 5. Inputs and outputs, crossing system (and subsystem) boundaries, may be tangible or intangible (material or information flow, for example).
>
> 6. There are internal domains of different function. For example, in a self-conscious system, there may be a domain of cognitive processes entailing perception, meaning generation, plan making, monitoring, etc., and a concrete domain of objects involved in processes such as the physical transformation of materials.
>
> 7. The system concept is not that of an entity which is ephemeral; there is long-run stability.

Now consider a traditional farming system with respect to these properties. The system has been traditionally bounded spatially by property lines. For example, decisions concerning aerial application of pesticides are focused spatially on the field in which the chemical is being applied. Recently concerns such as drift, over spray, etc., have become an greater priority in the decision-making process. Similarly, leachate in groundwater has not been a factor in the decision making on herbicide rates. The main factors have been soil type, crop and weed infestation. The spatial boundaries of farming systems have not only included property lines in the past, but also constrained the system to the surface (including the area from the root zone through the crop canopy). This constraint must change in modern thinking in order to incorporate effects by the farming system on its community. Organizationally, most U.S. farms are bounded by individual ownership. Corporate farms are organized at a higher level thus incorporating several individual farms; however, family farms may be viewed as single systems.

The farm system has subsystems which exhibit the properties of a system. One example may be the livestock operation of a grain and livestock farm. The livestock operation may be considered a coherent system receiving inputs from the grain operation of the farm.

The farm system has properties that result from the aggregation of subsystems. For example, profitability is a function of the timing of resources (Bender and McCarl, 1989). It is not possible to predict profitability of a farm by summing the profitability of each enterprise without considering the interacting demands on limiting resources. Limited man power or tractor availability often force the farm manager to compromise the optimal treatment of competing enterprises such as two crops.

Several systematic processes can be identified in traditional farming systems such as: transformation of seed, nutrients, light and water to food or fiber products; periodic financing cycles through the growing season; and production of feed animals from breeding stock and grain and forage resources.

Inputs and outputs which cross the farming system boundaries include traditional ones such as money, seed, produced grain, and fuel in addition to non-traditional materials such as sediment produced, chemicals leached, salt deposited from irrigation water, livestock waste, and wildlife.

The farming system and its subsystems have been contemplated by researchers, decision makers, and policy makers at several different levels of complexity. Most approaches have been reductionist in nature. Soft systems methodologies offer ways to expand the scope of the system and to study not only its parts, but the emergent properties of the whole.

SOFT SYSTEMS METHODOLOGY

The terminology and methodology of "soft" system approaches were developed throughout the 1970's primarily at the Department of Systems, University of Lancaster (Checkland, 1972). "Soft" system approaches differ from "hard" system approaches primarily in the nature of the problem. Problems that "hard" system techniques deal with have quantifiable inputs and relationships, so that specific results can be estimated for given conditions. Problems for which "soft" approaches are used often have goals and inputs that are more obscure and relationships that are more difficult to quantify. Typically a "soft" system approach is used to learn new information about the organization, communication, and control of a system (Checkland, 1985a). It also offers a methodology for formalizing this acquisition of derived knowledge. Soft system approaches seek to answer the following questions (Checkland, 1981):

1. What are the special characteristics of this kind of system?
2. Can the system be improved, modified or designed?
3. If so, how?

"Soft" system methodologies have been primarily applied in the management and social sciences (Checkland, 1985b; McLoughlin, 1986). No references to soft system approaches were found with direct application to agricultural problems. However, soft system analysis methods would enhance the management of interdisciplinary research teams and focus the individual's contributions and interactions. Teams which conduct diverse, interdisciplinary research efforts, such as the study of agricultural contributions to groundwater contamination, should begin their efforts with a study of the system of concern. This study should include identification of all significant subsystems, interactions between those subsystems, potential disciplinary boundaries, inputs and outputs of systems crossing disciplinary boundaries, the hierarchy of complexity and control, and connections with other systems outside of the system of concern. One formal method for conducting this preliminary information gathering is SSM (soft system methodology).

The SSM proposed by Checkland (1981) is a seven stage process. He suggests, however, that the "systems thinker" may be working on several stages simultaneously and at different levels of complexity. This informality would not suffice for an interdisciplinary research committee, so the author suggests that the team leader attempt to follow the stages chronologically.

The first stage of the process is an unstructured information collection stage before identifying the "problem". This is conceptually a simple concept - collect as many perceptions of the problem as possible before structuring a framework in which to define it. Although it is simple to conceive, it is difficult to put into practice because of the tendency to want to take action upon identification of any perception of a "problem". It is important to note at this point that SSM has been almost exclusively applied to human activity systems. In these types of systems, it may be very difficult to obtain a consensus of the "problem" from different participants within the system. A biological or mechanical system, although complex, should be more predictable (or at least repeatable) than a human system.

The second stage involves expressing the system from the most logical viewpoint for solving the problem at hand. It is important to have built up the richest possible picture of the system during stage one before constraining it in this phase. The crux of this stage is that it is not important or productive to work with the entire system at its lowest level of detail if it is not necessary for solving the problem. Checkland (1981) notes that "the function of stages 1 and 2 is to display the situation so that a range of possible and, hopefully, relevant choices can be revealed, and that is the only function of those stages."

Stage three requires that the relevant subsystems be identified and defined. Again, it is important at this point to consider carefully which subsystems in the full picture developed in stage 1 are relevant to the problem. These systems should be defined as explicitly as possible at this point, including their connections to other systems, their inputs and outputs from outside the system, and their processes. This must be an interdisciplinary effort void of jargon unless it is common to the entire team.

The fourth stage includes making and testing conceptual models. These conceptual models often fall in one of two categories: state models and transform models. A state model is often used with physical systems and includes a description of the elements which comprise it, their possible conditions (states) and their current state, their relationships with external elements which affect the system, and the states of those external elements. It is impossible to describe some systems, such as systems comprised primarily of humans, using this approach; therefore, another type of model is required. The transform model regards the system as an entity which receives inputs and produces outputs according to some process. This process might not be modeled based upon underlying principles, but it should be capable of accurately predicting output given some input.

Obviously, this phase is the most significant and time-consuming portion of the approach. It is also at this point that disciplinary contributions may need to be defined. If several scientists are constructing conceptual models of different subsystems, the interactions between those subsystems must be explicitly defined. This may be done through a network diagram with nodes representing systems and arcs representing inputs and outputs.

The fifth stage is comparison of the conceptual models with reality. The type of comparison used is dependent upon the structure of the conceptual model. The primary method; however, is to provide the model with the same input as the real system and compare their outputs. This phase is an iterative process with stage 4. When discrepancies between the conceptual model and the real system are discovered, a hypothesis about the cause of the discrepancy is tested by implementing the hypothesized solution in the conceptual model and running the comparison again.

Stage 6 involves identifying feasible and desirable changes. Once undesirable behaviors have been uncovered through stage 5, a list of potential changes should be compiled. Some of these changes may be feasible, some may not. This stage involves selecting those modifications to the system which are feasible as well as desirable. Changes may be changes in structure, in processes, in organization, or even in attitudes.

Stage 7 is simply implementation of the suggested changes. Effects of implemented changes should be evaluated through the use of stages 4 through 6. Often, implementing these changes may not be possible, but presenting an evaluation of the impact on the system if the changes were made is useful.

SSM has evolved from other problem management approaches such as the RAND Corporation systems analysis approach and an early paper by Jenkins (1969). Table 1 compares these approaches.

Perhaps the reason that we see few references to SSM in the body of agricultural science literature is due to its infrequent use. Individual scientists tend to tackle their disciplinary problems with little incentive for studying the broader picture. The author feels that the primary contribution that current work in "systems thinking" can make is not a general problem management framework as proposed by Checkland (1981), but the concept of considering the total system before reducing it into its elements. Through consideration and definition of inter-element streams of information, material or other types of flow, an interdisciplinary team can study a complex problem that overlaps disciplinary boundaries.

HARD SYSTEMS METHODOLOGY

The "soft systems approach" should continue to be developed and applied; however, problems in agriculture - and especially in groundwater protection - exist which have a higher level of structure and are more quantifiable (Barrett and Peart, 1982). Almost without exception, current research in the agricultural system is involved with advancing the understanding and quantification of processes underlying such issues as groundwater contamination. Many of these problems are amenable to a "hard systems approach". A common and useful synonym for "hard systems approaches" is OR.

As alluded to earlier, Checkland (1981) suggests that the distinction between "hard" and "soft" system approaches is the objective for studying the system. If the system is being studied with the intention of simply gaining knowledge about it, the approach may be considered "soft". If, on the other hand, the intention is to reach some objective through modification of the system (engineering), the approach is "hard".

> ...at the core of systems analysis [is] the idea that an important class of real-world problems can be formulated in the following way: there is a desired state, S_1, and a present state, S_0, and alternative ways of getting from S_0 to S_1. 'Problem-solving', according this view, consists of defining S_1 and S_0 and selecting the best means of reducing the difference between them. Thus, in systems engineering, $(S_1 - S_0)$ defines 'the need', or the objective to be attained, and systems analysis provides an ordered way of selecting the best among the alternative systems which could fulfill that need. The belief that real-world problems can be formulated in this way is the distinguishing characteristic of all 'hard' system thinking...
> (Checkland, 1981)

Most "hard" systems approaches documented in agriculture have emerged in the engineering literature. This should not be surprising since engineers tend to be interested in real-world problem solving, quantifying natural processes, and controlling natural processes to the benefit of mankind. The OR approaches of system optimization, modeling and simulation have been applied to several different domains (Anderson et al., 1977; Charleton and Thompson, 1970; Barrett and Peart, 1982). Plant growth simulations have been developed in order to determine the effects of management and input changes without actually having to grow a crop. Soil erosion models have been developed in order to predict the fate of transported soil and chemicals, as well as the effects of erosion on a slope over time. Crop mix and machinery management optimizations have been developed to indicate to a farmer the resource that is constraining growth in his opera-

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tion. Each of these applications relies on the ability to formulate a model at a relevant level of complexity that accurately and consistently predicts the true behavior of the system.

"The essence of the operations research activity lies in the construction and use of models" (Ravindran, 1987). It is important to note that models are necessarily an abstraction of the real system. They cannot, and in most cases need not, be exact replicas of the real system. Therefore, the development of a model requires that an *a priori* objective exist for the use of the model. Several reasons exist for modeling a real process: cost of constructing and operating the real system is prohibitive, inability to control some parameter (e.g., weather), time involved in experimenting with the real system (e.g., cropping years), etc. The modeling process may be described in three stages (Ravindran, 1987).

The first stage is the formulation of the model itself. This step requires that decisions be made about what aspects of the real system should be incorporated into the model, what assumptions can be made, how the model should be structured, what the goal of the modeling process is, and how the model will be manipulated. Formulation is somewhat arbitrary in that different researchers will rarely formulate a model in a similar manner due to their areas of expertise, biases of past experiences, etc. For an interdisciplinary team to formulate a model, much communication must occur and a large degree of trust must exist between experts of different disciplines.

The next step in the process involves deduction of predicted behavior from provided inputs to the system. This may include solving equations, running a series of computer simulations, or solving for inputs to the model to achieve an optimal output. This step is highly dependent upon the formulation of the model and the objectives for modeling the process. The evolution of the computer has enabled methods of solving complex sets of equations to be developed which were prohibitively time consuming without a computer. This partially explains the explosion of the application of OR techniques to agricultural problems since the 1970's.

Finally, the predicted behavior of the real system must be interpreted from the results of the deduction phase. This requires judgement on the part of the modeler and must be done cautiously. Careful attention must be paid to the assumptions and simplifications made in the development and implementation of the model and to the aspects of the real system which were intentionally or unintentionally left out.

Models may be derived from some hypothesis of the physical causes and effects within a system or from data collection. However a model is developed, before it may be confidently used, it must be validated. Verification is a weaker term than validation. Verification of a model means assuring that it "works" as intended. Validation, on the other hand, means that the model accurately predicts the behavior of the system. Several methods for validation exist.

The most significant contributions of systems analysis in agriculture have been in the domain of "hard" systems. Tait (1988) suggests that "hard" systems analysis and the "soft" systems approaches may be combined to provide a more powerful and comprehensive approach than either individual methods. This may be done by adopting a broader view than is common in the "hard" systems approach when formulating a problem and incorporating quantitative models for conceptual models where appropriate in the "soft" systems approach. A set of methodologies which will enable this hybrid approach to be implemented are emerging in the domain of artificial intelligence.

ARTIFICIAL INTELLIGENCE METHODS

Agriculture is an area of enormous potential for applications of systematic strategies which incorporate KBS (knowledge-based systems) and conventional technologies (Morrison, 1985; Coulson et al., 1987; Whittaker and Thieme; 1989). For example, excellent databases are available for information ranging from historical weather data to individual dairy cow records. Complex simulations have been developed to describe phenomena ranging from plant growth to economic systems. Such investments are valuable knowledge sources for knowledge-based decision making. A workshop was sponsored by AAAI (American Association for Artificial Intelligence) in 1988 to a) assess the state of the art of systems which integrate artificial intelligence concepts with systems analysis for agriculture, b) determine what factors are necessary to advance the state of the art, c) expose research needs and opportunities for the future, and d) form an interdisciplinary core of researchers for future communication and collaboration. The major topics addressed included: database integration with KBS (knowledge-based systems), simulation and optimization integration with KBS, and dealing with certainty in integrated systems. A discussion of the major themes arising from the workshop follows (Whittaker and Thieme, 1989).

Integrated knowledge-based systems can make existing conventional applications based upon modeling more accessible by providing a results interpreter and in some cases a model development tool. Several simulations have been developed within academic and research organizations that have not been used to their potential because they are difficult to apply. Even when such models and simulations are used, there is the danger that they are used inappropriately because of a lack of users' knowledge.

In some cases, KBSs have been integrated as intelligent data collectors to applications to remove the burden of syntax and format, and to apply domain-specific knowledge to request information from the user that is expressly required by the integrated application. In other cases, such systems can provide best guesses where the user is not able to provide input. KBSs have also been used as output filters, or data interpreters. Often the output of a simulation must be interpreted by an expert. Output filters make these programs more usable by providing higher-level inferences without the presence of scarce experts. Used in this way, the KBS may decipher the results of a simulation and apply it to the specific situation of the user. Robust simulations are capable of compactly representing very large spheres of knowledge and are valuable resources for knowledge-based decision making. This kind of integration effectively transforms a data-generator (the model) into a solution-generator by replicating known knowledge, i.e. by encapsulating the expertise of the model builder or expert user into a KBS.

The integration of traditional decision support models with KBSs also offers a promising methodology in utilizing incomplete and uncertain information to make risk-efficient decisions. Agricultural models, whether experimental or mathematical, provide a better understanding of real world systems; however, there are always assumptions which must be made and the potential of receiving imprecise inputs. The success of using agricultural models as decision support tools depends on recognizing how a particular inaccuracy can affect the interpretation of the obtained results.

Integrated systems will require more interdisciplinary research and development efforts. The concept of integrated systems suggests that interdisciplinary research and development efforts will take on a primary role. This can affect how funding is allocated and how research teams are organized. KBS technology has already highlighted the distinction between finding new knowledge in the agriculture domain and making that knowledge available with new technologies. AI can assist with both, but research funding is directed primarily toward the former. Thus, an important place is being made for the "extension researcher". Such a person would be responsible for applying new technologies and for delivering existing research products. It appears that researchers in agriculture will increasingly use AI techniques in classical research, as they now use conventional problem solving techniques such as linear programming and simulation. AI will thus become another tool in the researcher's library of tools, as opposed to an end in itself. However, since the primary domain of the agricultural researcher is not to develop such computing practices, more interdisciplinary work will be necessary between the providers of the application problems (agricultural researchers) and the providers of the computer solutions (KBS researchers).

An interdisciplinary research effort will also be needed for integrating risk and uncertainty concepts. Besides agricultural systems and computer programming expertise, at least one member of the interdisciplinary team must have expertise in decision theory. The researchers will need to concentrate on developing formal structures in probability and decision theory that address critical management needs. Research, extension, and industry need to be involved in coupling these formal structures with KBSs. And finally, extension, industry, and the end users must be involved to make the integrated systems deliverable and useful.

Deeper coupling will allow new kinds of problems to be addressed. Although the orientation has thus far been in applying existing KBS technology to agricultural problems to make solutions more deliverable, there is an evolution to new basic methods and techniques, e.g. deep reasoning, inferential databases, and qualitative simulation. In the future, researchers will need to use such technology to solve problems that were not solvable before. AI then becomes an enabling technology for researchers, rather than purely a delivery tool or an enhancement of current techniques. The knowledge represented in the knowledge-based portion of integrated systems will become more deeply coupled to the algorithmic portion than it currently is. Truly robust systems will require that the system know not only what inputs to develop or what model to use, but also why.

Many KBS applications in agriculture are taking advantage of such integration. For example, object-oriented programming used in conjunction with rule-based programming is becoming more popular. The abstraction, encapsulation, and inheritance mechanisms that characterize such systems are necessary for a number of problems in agriculture, and are quite useful for providing integration with conventional applications. Blackboard architectures are being used to unite multiple knowledge sources of different types into a cooperative whole.

Incorporating risk and uncertainty will result in more robust decision making. There is a need for integrating KBSs with the incomplete and uncertain information associated with agricultural models. Available knowledge and information such as research findings, experimental data, and mathematical model output are extremely important for making good decisions. However, efficiently managing and utilizing this knowledge and information is becoming increasingly problematic. Furthermore, most of this knowledge and information is uncertain and imprecise. Therefore, the uncertainty features of KBSs will play an important role in selecting risk-efficient decision alternatives. Probabilistic methods for making decisions are becoming more common. The digital computer has made it easy to develop and implement these methods for solving a wide variety of problems. Reliability-based design and statistical quality control are examples. A related trend is the use of utility concepts for making better decisions with uncertain and imprecise data.

Recognizing the fact that risk and uncertainty exist allows us to make better decisions with less precise information. KBSs offer a promising technology for coupling risk and uncertainty concepts into an effective delivery tool to address this critical need.

SUMMARY

In the future, the distinctions between "hard", "soft", and "knowledge-based" systems will become obscure. Almost every new interdisciplinary research project will include an expert in systems analysis and will use a systematic approach to defining the problem.

As discussed, the technology is available to allow this to happen. Knowledge-based systems are offering a medium to integrate traditional "hard" approaches with human judgement and interpretation. New methods for optimizing complex sets of equations are continuously being developed. Simulation languages have existed since the 1950's and are also constantly being improved. Existing technical stumbling blocks to the widespread adoption of systems analysis are quickly being removed.

Professional conflicts do exist, however. When an engineer and an entomologist speak of a "model", they probably have two completely different concepts. An agricultural economist may have yet another view. This is a result of different evolutionary paths for systems analysis in different professions. If interdisciplinary teams are going to cooperate on projects, terminology must be standardized and understood by all. A definitive dictionary of terms for the project under consideration would be beneficial. This corresponds to stage 3 of Checkland's SSM. The author's experience indicates that this could be a time consuming, non-profitable effort due to the difficulty of reaching a consensus between experts in different fields. Each expert has their own "correct" definition of terms. There is also a tendency for some professions to project the image that they are the only qualified experts in systems analysis. For example, of the engineering disciplines, industrial engineering is most often associated with systems analysis techniques. It is important for each discipline to have systems analysis experts that can understand the problems and language of other professionals in that discipline.

Institutional obstacles are very similar to professional obstacles. Often disciplinary interaction is hindered by issues such as: to which department will the primary credit go, who is going to make the final decisions about issues that cross disciplinary bounds, what language will be used, etc. These obstacles can be removed to a great degree by initiating an incentive system which encourages this cooperation. For example, equal credit should be given to co-investigators for publication, project management, etc. if they are in different departments. Graduate students should be able to be shared. Laboratories space should exist that is temporary and "leased" by interdisciplinary teams for the duration of a project for location of personnel working on the research. Several other creative solutions are possible, but institutional administration must be willing and able to force some of the changes. There is a significant momentum of *status quo* operation to overcome at institutions which conduct agricultural research.

Potential policies that may enhance interdisciplinary research through systems approaches follow:

1. The organization of USDA research laboratories is shifting in focus from disciplinary studies to problem area studies. A number of scientists from different disciplines are housed together to work on a common problem. This concept should be encouraged in land grant universities through a "center of excellence" approach. These centers should have a sunset provision and should be considered temporary. National coordination through administration of funding should prevent overlap and ensure that the centers are located at universities with the highest level of potential.

2. Require documentation of the first three stages of the "soft" system approach (reviewed earlier) within implementation plans of federally funded projects consisting of interdisciplinary teams.

3. Establish a computerized "bulletin board" for the exchange of discussion on standard definition of terms which are used in different disciplines.

4. Develop a framework based upon object-oriented programming which allows knowledge and systems from heterogeneous sourc-

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es to interact at a "whole system" level. Create libraries of well-defined objects for use by scientists in several disciplines.

Systems analysis is an entrenched element of many research activities in the agricultural research community. The ability of artificial intelligence techniques to enhance other traditional systems methodologies is gradually being recognized. Through policy that encourages the use of these approaches, interdisciplinary teams can be more effective and efficient, research products can have a longer and more productive shelf life, and the viewpoint of the farming system can be broadened.

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DISCIPLINARY INTEGRATION IN AGRICULTURAL RESEARCH

by

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DISCIPLINARY INTEGRATION IN AGRICULTURAL RESEARCH

JUN 23 1989

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INTRODUCTION

Agricultural and related sciences, since their beginnings, have been largely directed toward the production of useful and practical knowledge. That direction was inherent in the authorizations of the Hatch Act but has existed for a much longer time. Since the early researches of Liebig, research in agriculture and forestry have in large measure come out of the surrounding agricultural culture. Barnes and Edge (1982) note that agricultural research has been part of the large number of sciences that are oriented to and carried out around specific human ends and objectives. Such goal-oriented research also included research related to computer science, ecology, forestry, medicine, engineering, and so on. Thus, a perception has developed of how agriculture and food production ought to be constructed, and scientists set out to construct the system. Krohn and Schäfer (1982) have argued that agricultural science in the past has not provided insights into why agricultural functions but rather constituted a design of how it must function. Progress in agricultural sciences has been the result of the visions of the people both surrounding and involved in the research as much as of progress in the development and skills of the science itself and the available resources for solid research.

Today, disciplinary knowledge is widely regarded as expert knowledge, as opposed to liberal knowledge (Marx, 1989). The prevailing assumption in the scientific community is that it is the most necessary kind. Like other sciences, much of agricultural science operates in a disciplinarian ambience fostered by the sense of its importance, the conventional and evolving academic structure, peer evaluation, and the in-depth education required for research-oriented (M.S., M.A., and Ph.D.) degrees (Rossiter, 1979; Kunkel, 1988).

Society has not only permitted but encouraged universities and other research institutions to engage in "pure" or basic research as one of the traditional and autonomous functions (Castle, 1980). Historically, breaking down problems of biological systems into reduced and researchable basic questions (reductionism) has surely led to extensive understandings of biological and economic principles which, in turn, have been captured in the technologies of agriculture. Therefore, academic agricultural research, for most of this century, like the concomitant business of education, has turned toward compartmentalization into a series of professional fields linked to academic disciplines and major economic and industrial systems (Bennett, 1986). This conceptualization and organization in education, science, and scholarship has become increasingly pervasive in faculty identity, professional development and career paths, employment and promotion of the faculty, and expectations of students. Disciplinary specialization has evolved in the twentieth century to become an effective and advantageous strategy to gain and transmit knowledge. Disciplinary research has thus become the traditional method of academic scholarship and research, and it has had its spinoffs in agricultural science.

But, while science in the United States was developing a strong disciplinary base, agricultural science was also developing a partnership system between state and federal science agencies and the Land-Grant Universities. Academic agricultural science is developed to the largest extent in the state agricultural experiment stations associated with the Land-Grant universities. The public agricultural research establishment also includes the Agricultural Research Service, Economic Research Service, and the Forest Service of the USDA. Federal funds allocated to the Cooperative State Research Service (CSRS), USDA, as well as institutional funds, are made available to 1890 Land-Grant universities, schools of forestry, as well as the state experiment stations. Funds are also available to colleges and schools of agriculture and other universities outside the Land-Grant designation. But institutions differ widely in the extent and ways that disciplines are used and structured in agricultural research. The system is not monolithic. Priorities and capabilities differ for each institution. It is in the research university setting and in USDA laboratories that disciplinary science sets the mode.

Organizationally, parts of academia also have been formed into multidisciplinary departments for purposes of administration and handling some activities that integrate disciplines. This is particularly true in academic units contributing to certain aspects of professional education: agriculture, engineering, health sciences, veterinary medicine, home economics, forestry and natural resources. These organizations have been abetted by associated research organizations that are mission oriented such as the State agricultural experiment station. But, even within the multidisciplinary departments, research activities increasingly have taken on aspects of disciplinary specialization, although varying levels of multidisciplinary research activity have surely developed. Agricultural science is evaluated increasingly on the basis of its contribution both to basic and disciplinary knowledge and to knowledge pointing to new technology, policy, and solution of problems.

It is the interests, incentives, and objectives within the agricultural sciences that are the principle concern of this paper. These are elements that are subject to critical evaluation[1]. Goals and organizational structures can change, but values are attached to ways of doing research (basic vs. applied, disciplinary vs. subject-matter vs. problem-solving research; "big" science vs. "small" science). This paper seeks also to examine the issues and values revolving about agricultural research and to lay out alternative actions by which these factors can be directed to more effective cooperative research. Issues and human values are involved because they affect incentives through implementation of institutional policy, interests by challenging the beliefs and intuitions of the scientists, and objectives, in turn, as each scientist chooses the scientific experiment that he/she will undertake.

Interests, incentives, and the objectives for the research are entwined. Interests are individual and private. They are derived out of the individual's background, knowledge base, goals, beliefs, and loyalties. Interests are important in various ways, such as choosing the profession or discipline and the research program undertaken, or in the interpretation given to a set of data. They can change with the age and experience of the scientist, but are less likely to change at the behest of external influences.

Incentives are related to the career orientation of the scientist and the fit of the workplace to his/her interests. Incentives can be provided through the reward system, of which one of the most important aspects is often scientific reputation and disciplinary peer recognition. The scientific or scholarly paper is the usual object of judgment in peer recognition. Incentives can be also the lure of the scientific adventure and the satisfaction of learning. They can be provided institutionally in terms of the award of tenure, promotion, salary adjustment and institutional and administrative support of the research. They can also be provided externally by grants and contracts which may expand, or co-opt, the research that can be accomplished.

Objectives may be set by the interests and skills of the investigators as well as the goals set by those who facilitate, support, and fund the research effort. They are influenced by incentives. Ideally, objectives are set following analyses of the problem and definition of the researchable question. But analyses and definition are influenced by the assumptions that are precedent in similar researches.

Interests, incentives, and visualization of the objectives will affect the scientist's decision of whether to accept the opportunity or encouragement to join in interdisciplinary research. Multidisciplinary research is usually more compatible with a scientist's interests and goals, because multidisciplinary research is an on-campus activity. Interdisciplinary interaction has not been a common activity within and between departments. Interdisciplinary research may require a scientist to relinquish some of his/her interests and freedom to select objectives and to accept other incentives. But changes are on the horizon which may make integrative research more acceptable, perhaps, even sought.

New research methodologies such as molecular biology, materials science, computer expertise, mathematical modeling, artificial intelligence, and policy studies are being used to expand research in a range of disciplines. Changing, then, are the mode and amount of communication among scientists. Research is no longer a solitary or even an individual activity. A supportive community of science exists, and it is also changing its character, to include an increasingly wider range of disciplines, outside and inside the colleges of agriculture and experiment stations. And, some of the methodological approaches being developed are integrative

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sciences by their nature. Systems science is one such discipline, but add also the ecological sciences, biochemistry, nutrition, climatology, marketing research, applied ethics, and others. And as sciences mature theoretically, the solution of fundamental problems may become of less concern and goal-oriented specializations become more important (Krohn and Schäfer, 1982).

RESEARCH STRUCTURES

Basic and Applied Research

The terms "basic" and "applied" research have been used so long and so widely that they may have lost much of their specificity of definition. Basic or fundamental research, however, may be thought of as scholarship and research which provides knowledge without prior justification via the usefulness or application of the knowledge. By definition then, applied research would be the search that feeds on the knowledge provided through basic research and attempts to solve the practical and useful problems. Basic research would be directed toward understanding the principles at work in the world around us.

Basic research is high risk research because the risks are high for failure to produce useful principles. The cost is justified on the historical experience that highly valuable discoveries have come out of high risk research. Applied research sets its goals more realistically. Its goals are often long term, but applied research more easily satisfies the public desires to gain quick solutions.

Basic research draws its reason for being because it facilitates applied research. Applied research draws on certain principles discovered in fundamental research. But, basic and applied research are not mutually exclusive. Basic and applied research are not necessarily done by different people. When basic research yields an incisive result or is especially creative, the temptations to race into applications of the new principle can be compelling for a scientist or scientific group, perhaps truncating that group's further development of the principle.

Disciplinary, Subject-Matter and Problem-Solving Research

Johnson (1986) defines research contributions to agriculture , food, and natural resources as (1) the development and dissemination of disciplinary knowledge, (2) subject-matter research, and (3) problem-solving research or activities. Disciplinary research in this paradigm seeks to improve theory, fundamental measurements, and the techniques and instrumentation in one of the traditional basic sciences as well as in ancillary disciplines such as statistics and mathematics. Some of it is relevant to agricultural problems. A substantial amount, particularly in the life sciences, is increasingly embedded in agricultural and related colleges. The basic disciplines feeding the agricultural social sciences, on the other hand, remain apart, in traditional university settings.

Subject-matter research draws on many disciplines to address a subject important to a fairly well-defined group of decision makers. These may be agricultural producers, homemakers, industry management, directors of experiment stations, government officials, and others involved in food and agricultural issues. Plant, soil and animal sciences, agricultural engineering, food science, and agricultural economics are typical subject matter departments.

Problem-solving research or activities focus on specific practical problems and are multidisciplinary and even multidepartmental. Problem-solving means research or activities designed to solve a particular problem for a decision maker who faces the particular problem. Johnson (1986) describes problem-solving as involving two kinds of data: the perceptions about factual knowledge and the perceptions about values, that is, about the goodness and badness about conditions, situations, and things.

Disciplinary vs. Multidisciplinary vs. Interdisciplinary Research

The collaborative interrelationships in agricultural research may be viewed as an operational structure as well as a functional configuration. Russell, Sauer, and Barnes (1982) suggest three organizational models. Schneider (1988) calls for a similar approach for the earth sciences. Similar definitions have been used in OTA commissioned papers (OTA, 1987). In synthesis, these forms of collaboration are:

1. Disciplinary research is conducted by one or more scientist(s) within a single discipline or subdiscipline.

2. Multidisciplinary research is investigation in which scientists from several disciplines are involved, but the research is planned, executed, and evaluated by each person separately. Such planning implies that specialists of several disciplines contribute to the completed plan but may not imply that they work together to resolve any cross-sectional conflicts between their separate contributions.

3. Interdisciplinary research is mutually planned, executed, and evaluated by participants from several disciplines. They interact within the framework of a tested method to assure that the analysis is internally consistent and that foreseeable conflicts are identified and resolved. In this model, the search for solutions takes precedence over efforts to advance traditional disciplines (Schneider, 1988).

Each of these models finds its place in modern agricultural research. The multidisciplinary pattern is functional in the academic environment. The interdisciplinary approach may be feasible and most desirable for mission-oriented research programs, like those of agricultural research centers (Russell, Sauer and Barnes, 1982). However, the continuing and even necessary dependance on reductionism in agricultural research, the desire of scientists to maintain disciplinary identification, and the compulsion for consolidated strength in graduate level academic programs has worked against direct adoption of interdisciplinary research in universities. In that use, the interdisciplinary approach would likely have to be a separate or add-on organization, external to academic departments. Interdisciplinary research can be undertaken in a second mode which recruits contributing scientists out of a larger group for the special effort. The planning and interaction are interdisciplinary, but the actual research may be carried out in the home laboratories of the participants.

Recognition and Implications of Research Objectives

The research objective determines the kind of disciplines and subject areas of study that can effectively be marshalled in integrative research. Research seeking understanding the problems of soil or water contamination, for example, might involve contributions from an array of available disciplines--biological, physical and social science. For example, the biology of a biodegradation is to be determined, microbiology might be employed. Hydrology and hydro-geology would be expected to provide description of the flows of contaminants in water supplies. Soil biochemistry or soil organic chemistry would be needed to deal with problems with organic substances and metals, and the uses of chelation, photodegradation, chemical degradation, and so on. But whether or not the interdisciplinary approach is created depends more on which of the external goals and objectives that are decided upon as being the most important than

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on the specific research objectives. It may just make just good social and political sense for a number of reasons to go the interdisciplinary route.

Key to which disciplines might be useful in any integrated research effort is the scientists'--and, perhaps, the administration's--views of the nature of both the research goals and objective. But, of equal importance, is the inventory of disciplines that is available and can be interested in the effort. The disciplines which are available may be a function of the earlier research and graduate education programs. In other words, earlier priorities in research may have established the mix of scientific capability that is or is not available now.

DISCIPLINARY INTEGRATION

Reductionism and Integration

At this point, it may be useful to return to a conceptualization of the historical accomplishments of agricultural science. Whether one agrees or not with the outcome as direction of agricultural research, one must agree that past agricultural science symbolized great progress in developing instruments of control of the physical and biological environment related to food and agricultural production. Reductive science clearly played its part. But, the effectiveness of agricultural sciences has evolved out of something more than reductive science. Significant progress often came when the interpretations of phenomena by reductionists and holistic biological understanding concurred (Slater, 1988). Such concurrence occurred with the discoveries of quantitative genetics and the recognition of opportunities for applying plant and animal breeding toward agricultural development. Similarly, no element of basic biochemistry was more important in the transformation of animal agriculture out of the constraints of traditional farmyard environs than the discovery and isolation of vitamin

B_{12} and the concurrent realization by animal scientists that vitamin B_{12} was the intensively sought "animal protein factor", a final key to nutritional formulation of animal feeds (Scott, 1986).

As life sciences have matured theoretically in the second half of the twentieth century, there has been an evolution in the questions being asked away from those of the root general sciences (Rose, 1988a). Chemistry, for example, is an essential part of what is needed by biochemists and other biological scientists, but only a part. Rose (1988a) points out that while problems of traditional chemistry concern molecular structure in their own right, those of biochemistry concern the function of those molecules within a system, and neither the system nor the function of the molecule can be explained merely by the study of the molecule itself. Perutz (1988) quotes Karl Popper's assertion that a chemical reaction in vivo is different from the same reaction in vitro because in vivo; it works with a purpose. Slater (1988) agrees that chemistry is concerned with the structure of a substance and with the reactions that can take place between it and other substances. Biochemistry is concerned with the reactions that do take place in the living organism. It is in making biological sense where biochemistry or molecular biology go beyond chemistry and are not reducible to it.

Take this idea further into a hierarchy of biological and, after that, of social issues relating to biological systems. Biochemistry is a part of the studies of the development of organisms, but developmental biology is not wholly reducible to biochemistry. Ecology is not reducible to developmental biology. Economics is not reducible to ecology or human behavior. Agriculture and resource development are not reducible to ecology or economics, although it remains legitimate and important to describe some agricultural phenomena in terms of economics, ecology, human behavior, developmental biology, biochemistry and even chemistry. Each level in the hierarchy of sciences picks and chooses what elements of other science it wishes to incorporate and, in so doing, it becomes a scientifically self-sufficient, albeit truncated, domain.

But, reductionism in science has philosophical as well as scientific meaning. Reductionism, according to Levy (cited by Rose, 1988b), is a method in which the attempt is made to hold external conditions constant and modify only one factor at a time. This remains almost the only way we know how to design effective experiments (Rose, 1988b). But, reductionistic research is always done with certain assumptions in mind. Such scientific assumptions are abstract and have built-in values. According to Levy, in reductionism as a philosophy--a way of explaining the world--one must not forget that the studied "isolate" must be reinserted into the "blooming, buzzing confusion, the rich interconnected complexity of the real world, if we are to be able to interpret it meaningfully." Rose (1988b) goes on to say that "it is just such interconnectedness which reductionism, confronted with such profound biological issues as the development of organisms, the functioning of brains, or ecological diversity, finds hard to cope with."

From a philosophical view, integration would, by definition, be concerned with biological, physical and social issues and values and their interconnectedness in a particular context. From the methodological viewpoint, integration would be the engagement of various sciences (disciplines) to look at parts or isolates of the problem and insert these into the context or the critical solution of the larger problem. Integration, methodologically, also includes perceptions, sensitivities, communications, networkings, that is, the abilities to extract the necessary

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tools and knowledge out of reductive science and synthesize knowledge toward the solution of problems.

Evenson (1986) has developed a four tiered, hierarchical model which describes the flow and integration of knowledge from the basic, general sciences to practical implementation in a system. Evenson sees agricultural research slowly, and perhaps inexorably, reaching beyond colleges specializing in agriculture and life sciences, home economics, forestry and natural resources, and veterinary medicine into liberal arts, science, engineering, and business colleges. At level I are the "general sciences": chemistry, physics, biology, statistics, mathematics, economics, philosophy, climatology and so forth. Level II consists of "pretechnology sciences," analogous, in many ways, to the preclinical sciences of medicine. These are largely specialized disciplines oriented toward technology production. They include, but are not limited to engineering sciences, physiology, soil physics and chemistry, applied economics, ethics, nutritional biochemistry, molecular genetics, molecular biology, and systems science.

Further downstream are what Evenson describes as "technology invention" activities: plant and animal breeding, engineering design, irrigation methods, chemical development, farm management, policy studies, food science, and veterinary science. Biotechnology will settle to this third level as well. At Level IV are what Evenson calls "technology screening and subinvention" activities. These are required to adopt and adapt new technologies and are performed by agribusiness firms and extension services.

The general sciences have been concerned mainly with expanding the core of their science. Communication is horizontal, chemists with chemists, physicists with physicist. The general sciences have generally had little

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concern for technology, although that situation is changing. Pretechnology disciplines form the bridges and, hence, more or less the vertical or hierarchical integrations between the general sciences and technology invention activities.

Horizontal integration of several disciplines for research takes on a different form, usually in a multidisciplinary operational model or an interdisciplinary one. The organization may be informal, such as involved in spontaneous networking (Plucknett and Smith, 1984), or an organized institutional arrangement, or something in between.

Areas and Extent of Integration

Usually, integrated research focuses on a problem, commodity, or resource (e.g., forests, ground water) oriented activity, or a specified mission. Some agricultural research programs have been almost wholly multidisciplinary or interdisciplinary from their modern inception. For example, domestic and international rice research, international corn and wheat research, research on citrus, sorghum, poultry, some horticultural crops, and brush control have been integrations of disciplines that have produced remarkable progress. In each of these programs, plant and animal breeders, nutritionists, physiologists, food scientists, entomologists, pathologists, economists, engineers, and others collaborated to devise and adapt the production-marketing-management system.

Although the title might indicate disciplinary integration, integrated pest management (IPM) evolved first as a paradigm out of integration of methods of control of insects. Disciplinary integration in IPM research became significant when nationwide interdisciplinary projects were organized in the 1970s (Frisbie, 1985). The Consortium for Integrated Pest Management, a project initiated in 1979, was designed to enlarge the basic

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knowledge of managed agricultural systems that stressed profitable crop production, the ecological basis for reducing pest damage that would lead to application, the conservation of energy, and the improvement of environmental quality (Miller and Clifford, 1985). It was a project nationally supported, interdisciplinarily planned and conducted. It was a project with lofty goals. Its history may be instructive in planning integrative research in the future (Croft, 1985).

The Consortium for Integrated Pest Management (CIPM), a 17 university, interdisciplinary research project on four major corps (alfalfa, apple, cotton, and soybeans) was initiated in 1979. It was built on the scientific basis of an earlier project, the "Huffaker Project" which spanned 1972-1978. The Huffaker project was jointly funded by the National Science Foundation, Environmental Protection Agency and the U.S. Department of Agriculture. The project was initiated at a time when there was interest in establishing ecological principles that underlie the management of insect and mite pests. The Huffaker Project introduced and used system science and modeling as a way to organize, focus, and quantify biological (crop and pest) systems.

The CIPM project was funded by the EPA from 1979-1981 and by USDA/Cooperative State Research Service from 1981-1985 (Frisbie, 1985). Approximately 253 scientists across eight disciplines from 17 Land-Grant universities participated. Participating scientists developed a common goal to develop research to enlarge the basic knowledge of major managed agricultural systems that stressed crop productivity and profitability, the ecological basis for reducing pest damage to guide application in the field, the conservation of energy, and the improvement of environmental quality. The objectives set supported the common goal. The project was administered by an Executive Committee. University coordinators provided individual university guidance, local review, and accountability. The CIPM project underwent annual reviews as was a part of the State Agricultural Experiment Station reporting system. The project was judged to have met its goal of improving integrated pest management system, implementing the findings of research, and of increasing benefits to farmers and society.

The challenge in the administration of the CIPM project was the development of a structure that was flexible enough to allow for maximum scientific freedom and creativity, yet meet the research goals that were imposed upon the project by the participating scientists (Frisbie, 1985). A high standard of leadership was the objective of the Executive Committee. Accountability was maintained. Communication was augmented by workshops on ecosystems modeling, economic evaluation, and biological control. Thus, the management of the project also could be counted as successful.

Successful integrated researches have had the characteristic of focusing on relatively defined agricultural systems or on the development of research paradigms in which the players could be identified, even though their physical locations were geographically dispersed. However, most other areas of agricultural research function with increasingly disciplinary division or with the redundancy and site specificity necessary for applied research in the widely varied conditions of soil, water, climate and market. Thus research on major crops--corn, cotton, beef, dairy, poultry, forests--appear to be integrated only within certain institutions, such as a state agricultural experiment station or Land-Grant university, or as a function of communication in multidisciplinary professional societies and journals.

Integration may be conceptual rather than collaborative. And, that may have value in its own right. Integration may be hierarchical or vertical biologically, such as is now seen with the sciences involved in integrated pest management (Croft, 1985):

Genetic or epigenetic mechanisms
Organelles
Cells
Organ systems
Organisms
Populations
Life systems
Ecosystems
Communities
Ecosphere

But, the integration can also be oriented to the functional--and judgmental if policy development is involved--and requires another set of perceptions:

Ideas through validation
Actions
Tactics
Strategies
Insect management
Pest management
Crop production
Farm production
Agrosphere (including water resources, soil stability, community, landscape)
Anthrosphere (including consumers, food product chains and international markets)

Certain integrations must occur between the biological, scientific hierarch and the functional hierarch. Integrated research may focus on only a limited number of these levels of biological and management complexities. It is important for scientists to be able to envision the associated interrelationships at higher and lower levels of hierarchies.

Timing of Integration

Multidisciplinary and interdisciplinary research operates within temporal as well as structural and philosophical frames. The goals, support system and organization of integrated researches are critical to success, but the extent of development in the knowledge bases and maturity of the component disciplines are critical as well.

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Directed interdisciplinary and multidisciplinary integration in research does not generally occur without incentives. And, incentives may evolve too slowly on their own momentum. Strong leadership (lay, scientific, or administrative), a sense of urgency, crisis, or a seminal scientific discovery can provide the forces to speed the process, and these are time-related events. The emergence of the insecticide-resistant bollworm and its resultant disruption of the cotton production system of the 1960s was a catalyzing force in scientific collaboration leading to integrated insect control. The vision of opportunities to make further expansion of the paradigm led to the consortium for integrated pest management of the 1970s and early 1980s. The outbreak of Southern leaf blight of corn in 1970 and 1971 stimulated a major collaborative effort. The timing of the integration, as well as the integration itself, is determined mainly by the sense of need.

Systems Research

The foregoing has emphasized the human aspects in integrating disciplines in agricultural research. What can modify and is modifying the human interaction are major changes in the way research scientists can communicate. Communication devices such as interactive computers, computer links, telefax machines, and overnight mail speeding manuscripts and computer discs are remarkably increasing the capabilities of human interaction. Computer-based decisions are extending the communication process itself.

Computer-based decision aids can serve as a cache of information, perhaps adding a new requirement of integrated research: the database. Expert systems can serve as a means drawing and synchronizing diverse knowledge and technologies to provide for development of tactics and strategies for application. Interpretation of information from a variety of sources can be initiated. Human interpretation may need to be injected at this point, because each discipline has its own metaphors and sense of reality. The computer-based decision aids react by analysis of a user-supplied problem or goal. When the nature of the problem is defined, the system can select pertinent information related to it.

A "soft" systems approach--systems thinking--presents a methodology, emergent out of the business management sector (Checklund, 1981). It is fundamentally a learning technique. The system brings together logic and intuition, valuing, and doing. It involves reflection on reality, abstract conceptualization, and then comparison with reality. Anthropologists have devised a related method to study decision-making, the decision tree (Bennett, 1986). The trees are constructed as interview and observational data accumulate and represent a generalized mode of the thought pattern of the investigator. As a research technique, however, the soft systems approach, or the decision tree has not yet had significant use in agricultural research.

The concept of systems research demands application also of a different theory. Much of agricultural research in the past has been directed toward a production-oriented, maximization style. This goal sees agricultural management (decision making) as an aggregative activity, but the research base has been commodity oriented. Hierarchy theory such as that inherent in integrated pest management (Croft, 1985) can explain limits of aggregation in policy analysis. Hierarchy theory posits constraints from outside the system of production and these cannot be reduced to costs and benefits within the system. What is needed is a conceptualization of the limits of the system, say, one that respects the needs for agricultural production but one that respects the constrains in the larger natural system.

ADMINISTRATIVE DIRECTION AND COORDINATION FOR INTEGRATED RESEARCH

Fox, Evenson, and Ruttan (1987) found that both "basic" and "applied" research can be useful catalysts of technological change, and that little is gained by substituting one for the other. Disciplinary specialization is characteristic of each mode. However, scientists from various disciplines have different interests at stake. Polarities exist in the way agricultural research is viewed, some of which Johnson and Wittwer (1984; Kunkel, 1988) categorize in these groupings:

1. Some biological and physical scientists have argued that resources used in problem-solving and subject-oriented research would be more productively used for basic research. Such views, from within and outside the agricultural research establishment, may reflect a concern over who controls available resources (Johnson and Wittwer, 1984). It also carries a sense of primary importance of disciplinary sciences. Critics within the establishment argue that changing scientific frontiers, evolving social values and governmental roles, fiscal constraints and political realities require a change in emphasis from "agricultural science" to "science for agriculture" (Rockefeller Foundation, 1982), and a new look at the kinds of science needed for this research.

2. Users (the decision-makers who are served by agricultural research), and those who speak concern for them, are concerned about the changing structure and balance in agricultural research. Many agree with Schuh (1986) that "the frontiers of basic knowledge are far removed from the many problems of society," and that problem-solving research and

technology invention are needed for continued public support of agricultural science.

3. Other concerns are sensitive to the boundary between the physical, biological, and agricultural sciences; and the humanities and social sciences. Agricultural scientists and economists have both worked within the traditions of logical positivism, viewing the world as empirically knowable through testable deduction. Ruttan (1987) has described agricultural scientists as "reluctant revolutionaries" who want to revolutionize technology, but prefer not to consider the revolutionary impact of technology on society. There is also a call for more attention to issues of food safety and nutrition, farm worker safety and job security, public health, ecological protection, "low input" or "sustainable agriculture", and the vitality of rural society (Berry, 1977; Dahlberg, 1986). Ruttan (1986) observes that economic and social forces have driven technical and institutional changes designed to manage science more effectively. This is evidenced now in the area of nutrition policy. Animal science, for example, now seems philosophically tuned to public health and nutrition guidelines (National Research Council, 1988), whereas a few years ago the philosophical dichotomy between the livestock industries and public health advocates prevented this (Kunkel and Thompson, 1989).

4. Finally, some critics come from the ranks of those who hold that one cannot separate fact from value, science from ideology. They perform a useful service to society and food and agriculture, but some ask for what investigation and research cannot provide (Johnson and Wittwer, 1984). They are fearful of the release of genetically engineered microorganisms. They are concerned about any cancer risk, the demise of the family farm, the exploitation of resources, and the rights of agricultural animals. Some

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defenders of agricultural research against ideological critics, on the other hand, may lack objectivity and fail to recognize the limits of the system in their responses to these critics.

These varying interests form a backdrop to administrative issues in the integration of scientific disciplines. Overall, the critics speak mostly of the satisfaction of the various clienteles with the agricultural research, instead of the specific disciplines which are engaged in agricultural science. But different "world views" are characteristic of scientists of different disciplines (Kunkel and Thompson, 1989). As disciplines have been defined and specializations institutionalized, not only have constraints arisen to multidisciplinary and interdisciplinary interactions (Bonnen, 1987), but the reward system prioritizes disciplinary problems over problems of societal concern. Important problems may be ignored if they fall outside a particular discipline. Busch and Lacy (1983) suggested, for example, that earlier entomologists failed to address the effects of pesticides on people and animals and that animal scientists, at first, ignored the issue of waste from confinement of livestock. Even social science research excluded certain social perspectives. For example, production economics and price analysis give almost no basis for understanding consumer behavior or the entrepreneurial aspects of management (Padberg, 1987). Nonetheless, many scientists do learn experientially to break the bonds of specialization. And progress has been made toward consideration of broader societal goals, although, in the eyes of some critics, it remains inadequate to the needs.

Administratively, the general, desired model would seem to be that the disciplinary sciences be set somehow in a hierarchical arrangement which would encourage communication from the relevant disciplines through subject-matter research into problem-solving and, in turn, feedback through the system. University administrators have a responsibility for facilitating the access that social and other scientists need to those outside the colleges of home economics, agriculture and natural resources or the agricultural research institution without casting aside the component staffs of the college. The linkages to other disciplines are essential for vitality of institutions and the agenda of the relevant agricultural sciences. Substantial amounts of disciplinary research, particularly the life sciences, are increasingly embedded in multidisciplinary and disciplinary departments and units in academic colleges related to agriculture and in free-standing (Federal) agricultural research laboratories. But, the basic sciences feeding the rural and resource-related social sciences are located mainly outside of the agricultural and kindred colleges, that is, in the traditional settings of the university.

New divisions of the faculty to work on disciplinarily integrated "lines" of research (subject matter and problem-solving research as well as disciplinary problems) also are absolutes for the future. That will require groups of scientists from different disciplines, some once foreign to each other, working together. And that obviously includes mixed social science/biophysical science teams as well as teams of wider ranges of social sciences and humanities. There are also needs for accelerating the research process; teams of scientists which hold allegiance to the same discipline but provide different skills or interests may be needed to speed the work. Teams are common for work in the physical sciences and are increasingly seen in the biological sciences. They have been less common with the social sciences, in part, because such operational modes seem alien to those scientists who still tend to work in individualistic settings (Kunkel, 1987).

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Barriers in Administration

Disciplinary research, particularly that found in traditional universities, requires a minimum of administration (Johnson, 1986). The disciplines themselves set the logic and standards for research, and the need for direction of the research is minimal. Peer administration and review are common. The support base for the research operation is largely external grants. Individualism is dominant and collective agreement may not be sought.

Subject-matter researches, relevant to "real world" problems and decision-making, are much more difficult to administer. Called for are administrations that are able to overcome barriers of professional specialization and traditional structures that constrain integrative scholarship and the introduction of non-traditional disciplines. Institutional arrangements and organizations--interdisciplinary models, research institutes, stratified administrative structures, fundings for multidisciplinary efforts, budgetary priorities--have been tested and work so long as the reward system is adjusted to conform to the task, the unit is removed from the academic setting, or the needed special administrative momentum does not wane. But, in the academic institution, with existent inflexibilities and a certain inertia in funding, such arrangements may be limited in what they can do. The crucial unit in agricultural science remains the conventional multidisciplinary subject-matter department, which, in turn, requires a good deal more cooperation than is needed for a disciplinary department.

The multidisciplinary agricultural science department requires its scientists to be up-to-date methodologically for scientific research, for development of technology, for analyses of policy and institutional choices and of rational choices by consumers, and for building management systems. Keeping the faculty holistic in its thinking is expensive. It requires individual faculty becoming sensitive to other disciplines or, alternatively, the physical placement of staff out of other disciplines into the department—which seems to be the trend in some agricultural and related colleges—in order to gain the needed capabilities.

Voluntary Integration among Researchers

Despite the apparent constraints related to organization and, perhaps, of traditional staffing patterns, the potential for multidisciplinary research and interdisciplinary communication appears to be gaining. The reasons appear to be the evolution of the integrative and system sciences, the infusion of the same powerful new scientific tools into a number of disciplines, and the increased occurrence of informal on-campus networking among scientists of different disciplines. But, given that scientists' values and personalities intrude into research strategies, the future of agricultural research may rest, not on administration, but on the scientists' intellectual vision and philosophical awareness which go beyond traditional disciplinary limits.

Corrections to disciplinary isolation are underway. The disciplinary components of subject matter research are changing. Biochemistry, molecular biology and genetics, biotechnology, and areas such as human nutrition are being integrated into traditional subject matter departments (e.g., animal science and agronomy, veterinary sciences). Systems sciences and artificial intelligence are entering into most departments and activities.

There is also likely to be a redefinition of disciplines. For example, the methods of virology, structural biochemistry and expert systems are

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embraced by entomologists; systems theory and molecular biology occupy some plant physiologists; and political science, and perhaps epidemiology, are acknowledged by agricultural economists as legitimate tools of their science. Future research in agricultural economics, rural sociology, and home economics will likely engage people with expertise in business, applied anthropology, psychology, and applied ethics.

At least three forces appear to be driving research activities across disciplinary lines: 1) Integration of the sciences, and the emergence of the systems concept in agriculture; 2) Networking among scientists; and 3) A resurgence of the basic sciences, stimulated by biotechnology and the powerful new tools of systems theory and of the "new biology". As new tools in biology, economics, and social theory become shared instrumentalities in agricultural science, a new common interdisciplinary language will further enhance communication among scientists.

In the Great Plains region and rice production areas there have been experimental efforts with the integrated systems approach to production, facilitated by computers that can process large data sets and support integrated modeling. Expert systems have served to identify and couple critical disciplinary and multidisciplinary research efforts.

Networking among scientists, first documented among the International Agricultural Research Centers (Plucknett and Smith, 1984), and now increasingly important in agricultural research, requires voluntary problem sharing, mutual commitments of resources and perhaps start up funding. Peer respect is essential. Networking, however, is entering a new dimension (Denning, 1987). The new paradigm places people in the central role, supporting their conversations and collaborations. It will be based on networks of computers, fax machines, and telephones. The new term is not merely a data base or channel. It is more than scientists of different disciplines collaborating with each other. The new term, networking, refers to individuals, institutions, and services that in the future must communicate with each other.

Roy (1986) has suggested that science has been "redeemed from irrelevance" by the scientist. The best scientists, he argues, are versatile people, who on Monday are concerned with their science, on Tuesday consult with extension specialists or industrial firms, and on Friday advise the government on ecological or economic policy. In the final analysis, he believes, scientists will arrest disciplinary narrowing in agricultural research, if that is what should be done.

Directed Integration

If agricultural research is to overcome disciplinary barriers, new institutional arrangements may be needed. There are, obviously, cases where the antecedent goals or philosophical bases for agricultural research do not reach adequately toward meeting new goals. Self-moving, voluntary integration may not be adequate or developing fast enough to meet the time frame. Some aspects of integration are not likely to occur without administrative direction or conscious organization among scientists. Universities have experimented with institutes, centers, interdepartmental research programs, and similar arrangements. However, these survive principally because of special funding arrangements. Regrettably, too few have been salable as an intellectual focus in their own right (Schneider, 1988).

Obviously, funding policy or budgetary priorities can be used to encourage multidisciplinary and interdisciplinary collaboration. At a senior level of planning, institutions may establish goals that demand

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imaginative, interdisciplinary interactions via seminars, and multidisciplinary conferences, interdisciplinary publishing and reward systems, or other comparable feedback arrangements. Efforts of these kinds have been successful and have left a residue of a changed paradigm and scientific cooperation, even after the special funding was ended (Frisbie, 1985).

One of the more successful institutional arrangements for integrative research is the commodity-oriented interdisciplinary research centers (Evenson, 1986). The commodity-oriented interdisciplinary model is exceptional in United States public sector research, but has been successfully implemented in the IARCs--such as the international research institute in the Philippines (IRRI), the wheat and maize research center in Mexico (CIMMYT), the potato institute in Peru (CIP)--and in off-campus agricultural research and extension centers in Florida, Texas, and other states particularly for rice, citrus, and some vegetable crops (Kunkel, 1988). In some sense, this model replaces the need for scientific communication (Evenson, 1986). It is used in situations where skills of different research fields are required, but the system does not need to facilitate sophisticated communication among scientists. Scientific publications are generally not stressed. The model is well suited, however, to certain short-term research problems, but can also take advantage of more fundamental research by hiring researchers trained in the pretechnology, disciplinary sciences (Evenson, 1946).

Stratified administrative structures, which may reflect an interdisciplinary model also exist in "Big Science" where instruments cost millions: oceanographic research vessels, space probes, particle accelerators, ocean drilling projects and the like. Despite commitment to academic research styles, the administration of such a facility, employing many scientists and a large technical staff, cannot be as participatory or egalitarian as a discipline oriented department (Ziman, 1980). The personal commitment of the researcher to the advancement of knowledge is expressed in terms of allegiance to the project or institution, and to the knowledge corporately produced. Traditional incentives to publish may be replaced by pay raise, promotion, special privilege, or devices such as multiple authorship. Any values introduced are provided by management or the society whose representatives vote appropriations. For agricultural research, however, "Big Science" has generally not become a viable approach in the public sector. There have been some attempts in total population control of insects that could be said to fit the "Big Science" pattern, but implementation of research involved federal agencies, state institutions, and farmers (Perkins, 1982). Farmers are notably entrepreneurs. Save for the remarkable successes of screwworm fly eradications from Curacao and Florida and its suppression in Texas, the Southwest and Mexico, the lack of scientific consensus and the need for applications that were location specific has probably discouraged the large centrally directed project approach (see Perkins, 1982, pp. 265-285).

Organizational solutions at academic institutions can only go so far in the face of institutional inflexibilities, and in the context of today's scientific reward system and allocation of resources. As federal, and hence academic budgets are trimmed, programs without a departmental base are the most vulnerable (Krimsky, 1988). Interuniversity competition for funding and prestige is pervasive and strongly enforces the dominance of disciplines throughout higher education.

Resources Needed for Integration

Funding. Directed integration of disciplines, as noted above, is more expensive than spontaneous or naturally flowing integration that comes out of mutual interests developed among scientists. Funding allocated for new research goals can also be a powerful means of interesting and recruiting scientists of various disciplines to contribute to the integrative effort. Either way, multidisciplinary and interdisciplinary efforts are facilitated by funding policy or budgetary priorities. Funding moves the time frame forward toward scientific attention to the problem.

Directed integration--whether it be through institutional administration or action of the Congress--uniformly requires directed funding. It is a matter of incentives. A reward system of some sort must be put in place.

Education of Researchers. For many years, agricultural science drew its scientific corps from the ranks of those who has agricultural experience, usually in their youth. Although such experiences may have influenced the subsequent interests of agricultural scientists--and perhaps accounts in part for the sustained interest in research relevant to production agriculture--such experience was a powerful force. Experiential knowledge is powerful because it summarizes. It is a combination of learned principles and rules with experiential knowledge that give the leaders of integrative research and experts significant capability. But, the availability of students coming to agricultural sciences with appreciable experience in an agricultural system has diminished greatly, although enrollments in graduate programs in agricultural science are still being maintained by some very capable students. What is needed is a component in education that substitutes for their intuitive knowledge, or perhaps, more importantly, stimulates certain number of the scientific corps to develop the capability of "summary" or perception of the system.

The hierarchical nature of disciplines in biological or other research suggest that the educational flow is more likely from the general, more fundamental science to the more broadly constructed science relating to the complexity of the organism or issue. Biochemists become versed in chemistry but some take individually selected incursions into organismic or ecological science. And, so it is within each of the disciplines. Most problems requiring integration of sciences can probably find somewhere, somehow the scientists to provide the mosaic of expertise that is needed for the problem.

It is not known how serious it might be that some traditional disciplines--e.g., taxonomists, quantitative geneticists, crop-oriented scientists, anatomists--are greatly diminished in numbers. Some new areas of national need have been identified and some special support has been provided through the USDA Office of Higher Education Programs for enhancing the quality of student scientists entering these fields. We are dependent upon the current graduate education system for renewal of the research corps. Analysis of the potential output of that system is in order, and, if needed, corrective action taken.

An advanced technological agriculture cannot likely continue without constant replenishment and update of its reservoir of expert knowledge. Therefore, what is probably the more important add-on of the education of researchers as a resource for integrative research is a component of education which also looks into the philosophical approaches in agricultural science. That would ask forthrightly questions about the major themes and concepts about agricultural research. Students with such understanding,

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though thoroughly schooled in a discipline, should become a better resource for integrative research.

Administrative Resources. Few new thrusts move forward without enlightened administration. It is now recognized that outstanding administration of the IARCs was needed for the successes of these Centers although, clearly, highly competent individual scientists were at the heart of the successes. The administrative decisions leading to the establishment of the commodity-oriented, multidisciplinary research and extension centers of The Texas A&M University System and the University of Florida has led to an unquestionably effective facilitation of integrative research, much of it inter-disciplinary. (Whether this is the model for other opportunities for moving financial resources in other areas is unknown.) And, while the problem of scientist renewal at such diverse centers has not been solved, the IARCs and the research and extension centers have also become central to networking for research.

The encouragement of the administrator and institution are crucial in facilitating voluntary integration. Integration of research, as noted above, can be facilitated by special allocations or funding. But the policy of the institution and the development of a favorable ambience can go a long way toward fostering the cooperative attitude. Administrators who understand human relations and act responsibly toward the scientist corps will be repaid with successful activity.

Objectives and Planning

The objectives of any research program must rest on firm scientific bases. But, although the discernible parts of the problem must be researchable, the need to develop an organized, systematic approach is central to establishing the goals of the integrated program. The challenge

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is to develop a structure for integrated disciplinary collaboration in research that is flexible enough to allow for scientific freedom and creativity, yet meet the research goals that are asked of the project by participating scientists, administrators, and external interests. External interests--users, the public, the Congress, government--can and do participate in setting the research mission and the goals for research programs. Clearly, external interests can facilitate research by providing moral financial support and, to some extent, political strength. It follows that government science policy can be a powerful directive force.

Specific objective setting to meet the goals, however, remains a function largely of the scientific participants. The definition of important problems which are researchable call for first-rate minds who will rebel at inappropriate formation of the problem (Castle, 1980). The researchers and their institutions must provide the vision. The situation, however, does not foreclose a broadly based planning effort. Scientists of wide geographic areas and varied disciplines can sit together and plan. Again, we note the multiuniversity, interdisciplinary Consortium for Integrated Pest Management research program (Frisbie, 1985) as an important model.

As noted earlier, for a significant part of the history of agricultural science, agricultural scientists have shared a view of what agriculture should primarily be with the agricultural culture, i.e., farmers and ranchers and the infrastructure supporting production agriculture (Barnes and Edge, 1982). And they set their research objectives accordingly. Younger disciplinarians of today know less of agriculture's history and institutions, but, in turn, they also may be more open to the broader recognition of the clienteles of agricultural research. They are likely to have or develop different interests than scientists of earlier decades. And, this may be a valuable, albeit less predictable, evolution in the scientific corps. The disciplinarian of today may be brought more easily into the "fold" of integrative research and fill the serious gaps in agricultural science than those who had the "intuitive" knowledge of the agriculture of the past.

Strong versatile leadership can encourage strong disciplinarians, on a selective basis, into collaborative research. Strong leadership can guide the intellectual vision and philosophical awareness needed in setting goals, planning, and recruiting scientists to contribute. If a specific component of the research fits the interest of a prospective participant, recruitment is easier. Expression of institutional, societal, and national priorities through fundings can provide the incentives of research support. If priority is given to competitive proposals that are collaboratively and interdisciplinarily formulated, more integrative research will be done, even on a university campus. Such an announcement in funding of expanded research at the Texas Agricultural Experiment Station in 1989 almost completely eliminated the single investigator proposal. Peer review of proposed contributions can add to the sense of importance of the research.

Publication of interdisciplinary research is also becoming easier. Papers with multiple authorship are no longer unusual in some fields, particularly, in medicine and "Big Science" research. Interdisciplinary journals are appearing far more rapidly than libraries can absorb them, albeit a large number of these new journals tend to be published outside the United States.

A sense of security, too, for one's career can allow expansion of interests in arenas beyond disciplinary activities.

Given such factors, incentives can be crafted and interests turned toward research planning for integrated research. The skill that will be needed in agricultural science is to achieve a balance of both good science and relevance in employing, supporting, and setting goals for the research scientist.

POLICY OPTIONS

Agricultural research is at a crossroads. Although the agricultural sciences have a clear mandate to address societal needs, they are evaluated increasingly in terms of contributions to both general disciplinary knowledge and knowledge pointing to a new technology, policy or solution. As in medicine, this dichotomy of expectations poses a problem for agricultural sciences. Moreover, the issues of disciplines and their integration in agricultural research revolve around strategies to solve important and often complex problems which are also laden with human values. There is likely no common prescription of how to handle these complexities. It is clear, however, that solutions in agricultural research are likely to come from both disciplinary and integrated researches, as long as both are present. An advanced technological agriculture cannot likely continue to be useful without constant replenishment and update of its reservoir of expert knowledge. But expert knowledge may remain ineffective unless there is a match between technological knowledge and a socioeconomic framework for implementing the technology. Seeking both good science and relevance should be a significant point in research management and research policies established by Congress, the USDA and other agencies which carry out or support research related to agriculture, the States, and the universities.

It is in the reach for the twin goals of good science and relevance that integrative research becomes important. Several routes are available

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for integrating sciences. One important strategy is the development of centers, institutes, consortia, task forces, or other administrative devices, to carry out the inter-disciplinary mission or goal. A second way is the more open multidisciplinary, sometime multi-institutional, route common to many successful collaborations in the past. In any case, a number of mechanisms are available for developing imaginative, feasible, integrative research objectives and communication among scientists. But which mode of integrative research is to be chosen depends on factors in addition to the research goals. Effectively changing the administrative structure changes primarily the communication among scientists, although new goals are also formulated and new initiatives can be gained. The approach may depend on where leadership can be garnered. A task force, for example, could be organized with a regional focus, or it could be coordinated at the national level by the USDA or other federal agency; alternatively, it could be initiative of a single university. The urgency of the problem may suggest whether a task force or a new interdisciplinary unit is created. The optimal choice among institutional forms is a mixture, not a single form. Neither the multidisciplinary approach, the interdisciplinary project, or the interdisciplinary research center is best under all conditions. The mixture, moreover, cannot be fixed. The communications and informational problems that are at the core of efficient choice among institutional forms are continually changing (see Weisbrod, 1989).

Various models have been devised for a trans-institutional mode of integration. A key model is that which facilitated the national integrated pest management research program, a program which embodied both interdisciplinary planning and an open, peer-reviewed granting system to ensure quality of the research program. But, joint planning, involving a number of investigators and research leaders, is a device that not only can change goals but consciously or unconsciously also can change interests. Joint planning or workshops, where people sit and debate the issues, can also establish new lines of communication among researchers which may be reflected in other collaborative efforts.

Education and communications are aspects that impact interests. One would expect that something more should be added to education for a research career. A course embodying integrative scholarship--for example, a systems course, a "capstone" course for the subject, a course in society and technology--might be required of graduate students to sensitize them to the kinds of problems that are best served by scientific integration or systems science. But, changing the fundamental concepts of education in the agricultural science may be a better solution. A number of fields, including agriculture, are struggling with what should be the content of undergraduate and professional education in the light of major societal changes that are occurring. Those studies should receive continuing support.

For those who are beyond their schooling, the issues needed changes in interests are somewhat more difficult to solve. We have used conferences, seminars, continuing education, visiting professorships and the like, but with varying successes. The well-written book may achieve more. But, few books exist that look at interactions, interrelationships, and issues in agriculture. Grants for writing books on integrated sciences may be very useful. Consideration ought to be also given in each project or program to assistance of institutions to enable there capacities to communicate and to utilize systems methods: computers, on-line networks, telefax equipment, as well as the traditional, face-to-face conferences. A policy that

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facilitates communication and informational exchange, would be most important in integrative research.

Faculty members and scientists are highly creative when put to the task. It is more often a question of leadership and the reward system. Better methods ought to be devised to reward the scholar and scientist whose intellectual syntheses goes beyond contributions to the science itself. In some measure, such rewards come when scientists sit on advisory panels or serve as consultants to federal agencies, the National Academy of Sciences, and industry. But these opportunities have limited visibility and may not be accepted in peer evaluation. There are some journals which publish such syntheses (for example, Science, journals of the American Chemical Society, BioScience, Issues of Science and Technology) and provide national visibility. Those who synthesize, however, are often the mature scientist and faculty member. It is the younger disciplinarian of high competence for whom we want to provide incentives for her/him to engage in integrative and collaborative science. This is the individual who most severely faces the inflexible reward system, because she/he has been recruited competitively with the very thought that here is the one who can most likely exceed the standards of the reward system. Obviously, some way of building the prestige of multidisciplinary and interdisciplinary research is as important as the incentives of security of career, income and recognition.

These are policy issues for the Congress, the government, the USDA and other science agencies, State, and universities. It is evident that attention will have to be paid to the process, as well as the goals of research. But the larger goal of reaching for both excellence in science and relevance to society's needs is an imperative.

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Notes

1. For purposes of this paper, the term goals will refer to the goals for the research. Goals may be institutionally, externally, disciplinarily, or politically defined or driven. Goals for agricultural research, for example, might be for enhancement of a commodity oriented research program (such as on corn or blueberries), of studies relative to a resource (such as on air quality effects, non-point contamination of water supplies, control of forest pests), of investigations relative to a use (such as research in international marketing, human nutrition) or otherwise. The term mission refers to the general purposes of the institution or program and may encompass the goals of the institution or for the effort.

The term objectives will refer to the objectives of the research itself or research program. Such objectives may be, say, increasing the yield of corn, producing a superior variety of crop, improving the nutritional quality of beef, developing a new means of genetically engineering a plant, or developing the understanding of a physiological phenomenon.

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LOW-INPUT/SUSTAINABLE AGRICULTURE RESEARCH AND EDUCATION: A REVIEW OF SELECTED PRIVATE ORGANIZATIONS' ACTIVITIES

by

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February 1989

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Stillwater, MN

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This contractor document was prepared for the Office of Technology Assessment (OTA) assessment entitled Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. It is being made available because they contain useful information beyond that used in the OTA report. However, they are not endorsed by OTA, nor have they been reviewed by the Technology Assessment Board. References to them should cite the contractor, not OTA, as the author; a suggested citation format follows:

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Low-Input/Sustainable Agriculture Research and Education: A Review of Selected Private Organizations' Activities

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Abstract

This paper summarizes findings from an OTA survey of 29 private, non-profit organizations. The organizations surveyed reported that agrichemical applications are the primary cause of groundwater contamination, and indicated that groundwater contamination is a serious problem. The topics of their research, the methodologies employed, the audiences they addressed, and the types of educational efforts made varied widely.

Research methodologies ranged from "scientific" research with carefully controlled variables in a traditonal university model to unsupervised, relatively unstructured, on-farm experimentation. Respondents emphasized the need for more involvement of farmers in research and greater involvement of university researchers with actual farms and farmers. They indicate that innovative, low-input strategies have been developed by farmers and that farmers are engaged in extensive on-farm experimentation. Both in university settings and on working farms, researchers focused on a wide variety of low-input farming practices.

But respondents report significant problems with research -- primarily in the focus of government and university funding on high-input practices and on increasing productivity. They call for a re-focusing of resources toward research in sustainable agriculture.

Information dissemination is also crucial. Many farmers (and others) still believe that low-input agriculture means a return to horse-and-buggy days and that its advocates are somehow "anti-agriculture." A variety of means of information dissemination are used by respondents. Many believe that the most effective method is farmer-to-farmer communication, and the opportunity to observe neighbors' use of low-input techniques suited to a specific area. A key problem with education is, again, university and extension service focus on high-input practices.

Most respondents agree that groundwater contamination by agrichemicals is a symptom of a larger problem with the entire system of conventional agriculture. They advocate solutions which address the systemic problem, including changes in government policies in the areas of support for alternative farming systems, changes in commodity programs, strengthening conservation policies, and setting new directions for research and education.

Low-Input/Sustainable Agriculture Research and Education: A Review of Selected Private Organizations' Activities

I. Methodology

Questionnaires were mailed to forty private, non-profit organizations which had been identified as involved in researching, evaluating or disseminating information on low-input/sustainable agricultural practices with the potential to reduce agrichemical contamination of groundwater. The survey was intended to be descriptive, not statistically evaluated. It asked for information on low-input/sustainable agricultural practices with the potential to reduce groundwater contamination by crop nutrients, agricultural wastes or pesticides. (See Table I for a list of respondents.)

Organizations surveyed were selected by the Office of Technology Assessment to represent a profile of groups actively involved in research and/or educational activities impacting groundwater quality through low-input and/or sustainable agriculture. These organizations were selected because they were either involved in USDA-funded LISA projects, listed in organization directories, or recommended by individuals with knowledge of the organizations. This survey did not attempt to cover all of the very large number of private organizations involved in such work. (OTA estimates that the total number of organizations involved in some activity of this type in the United States is at least 400.) Instead it focused on an in-depth picture of a small but geographically representative group.

The 16-page questionnaire asked each respondent to identify and describe its own work in the areas of research, education and policy relative to low-input/sustainable agriculture approaches to reducing agrichemical contamination of groundwater. Respondents were further asked to identify perceived problems and gaps in the areas of research and education and to make suggestions regarding agriculture and groundwater policies. In addition, they were asked to identify various types of organizations with whom they worked and organizations whose work in this area they admired. A copy of the questionnaire is attached as an appendix.

Twenty-nine organizations responded to the questionnaire. Two of these respondents indicated that they were not engaged in the activities surveyed, and did not complete the questionnaire. Thus the response rate is approximately 75%. This report is primarily based on findings from the survey questionnaire.

Where appropriate, citations are made to specific respondents' responses. Since respondents' comments on policy are considered confidential, the statements in the policy section are generally not supported by specific citations. Nonetheless, the generalizations made there and elsewhere are drawn from survey responses, not from the authors' opinions or any other source unless another source is specifically cited.

II. Organizations Surveyed

Respondents represent all areas of the nation -- nine from the West, nine from the North Central area, six from the Northeast, and five from the South. This geographic diversity is reflected in the diverse types of farming operations and sizes of farms respondents represent.

One respondent reports as typical a dairy farm of 296 acres with 101 cows and 3.2 full time equivalent workers. Another describes ranches with an average size of "a few to several thousand" acres. Others report cash grain operations ranging in size from several hundred to thousands of acres. California respondents focus primarily on smaller operations, ranging from 1-80 acres in size and producing primarily fruits and vegetables. For detail on types and sizes of farm operations, see Table II.

Types of organizations responding are also diverse. Seven respondents are all-volunteer, membership organizations. Budgets of the staff-led organizations range from $34,000 to $32,000,000 annually. Seven respondents report budgets less than $50,000, while six have budgets of more than $600,000. The largest number (eleven) are in the $100-600,000 range.

Ten respondents are organizations of, by and for farmers. Four are research farms. For detail on sizes and types of organizations, see Tables III and IV. Nine of the organizations have been around more than fifteen years -- a relatively long life-span for non-profit organizations. Four are very young organizations, founded within the past five years. Most fall in the age range of five to fifteen years.

All groups reported education activities. Twenty-three reported conducting at least some research activities, and ten devoted at least one FTE in staff time to research on reduction of groundwater contamination in 1988. (At least two others plan to increase research in this area in 1989 and following years, with the help of LISA funding.)

Organizational philosophies differ widely as well. All respondents point to overuse of pesticides as contributing to groundwater contamination. Some respondents emphasize organic farming, completely eliminating the use of synthetic agrichemicals. They typically describe a need to gradually reduce "chemical dependency" while moving toward a certifiably organic mode of farming. Other respondents are willing to contemplate long-term, continued use of pesticides, but emphasize reducing frequency and amount of applications. Strategies for reduced usage include techniques such as pest identification and spot-spraying for control of particular problems.

Some respondents are also concerned about overuse of nitrogen fertilizers on corn and other grain crops. Respondents who mention corn and soybeans do so in order to criticize the practice of continuous corn and soybean rotations, or of corn mono-cropping (see glossary.) But they focus at least as much on pesticide use as on over-application of nitrogen.

Only one respondent mentioned manure lagoons as possible sources of contamination. Another listed feedlot operations as a major agricultural activity in its area. The survey did not specifically ask respondents to identify sources of contamination, although they were asked if they were engaged in research on livestock waste management. One respondent in the Northeast area is engaged in extensive study of manure use, both from the standpoint of groundwater protection and in order to increase effectiveness of fertilization practices.[1]

None of the survey responses focused directly on irrigation as a cause of agrichemical run-off or leaching. Considering the areas of the country covered by the respondents, this omission seems unexpected. Farming in California is a heavy user of irrigation. In much of the Midwest irrigation systems are also familiar sights. It may be that respondents presume that irrigation systems do not cause groundwater contamination unless they are used in conjunction with relatively heavy applications of agrichemicals, and so discuss the agrichemicals as the primary difficulty rather than focusing on irrigation. Or it may be that private organizations are not focusing on irrigation. Conversations with respondents indicated emerging areas of concern about pesticide residues in irrigation water and about the increase in "chemigation" -- the spraying of agrichemicals along with irrigation water.

Lack of attention to manure disposal and irrigation may be symptomatic of a broader interest in pesticide applications and some lack of attention to nitrate pollution. (However, one respondent did focus primarily on nitrate contamination of groundwater through agricultural drainage wells.) An earlier study by the Minnesota Project[2] found that private non-profit organizations and policy makers alike neglected the major impact of nitrates:

> It's hard to understand why nonprofits and policy makers aren't more concerned about nitrates. The extent of nitrate pollution exceeding the drinking water standard is phenomenal. In many counties the majority of wells are technically undrinkable, yet for some unknown reason nitrate contamination

> is not viewed as a big problem. This may be partly because regulating fertilizer or manure is unprecedented.

The first draft of this report was reviewed by a number of persons involved in private non-profit organizations' work on groundwater contamination. Some reviewers gave other reasons for the lesser emphasis on nitrates in the groundwater:

> "Nitrate in groundwater may be biologically removed more easily than a pesticide, and may only pose an acute threat primarily to infants."

> "Finite resources dictate that we focus our efforts. Land grant universities ... historically have been more willing to address nitrate than pesticide pollution ... This may be because N can be a major expense in growing field corn ... Thus, it may be a logical division of labor and an indication of efficiency, rather than neglect, that PNP's focus on pesticides. Perhaps focusing on pesticides was a reaction to the lack thereof in the agricultural establishment; PNP's may fill a void."

Among the respondents who focus on research, there are wide differences in philosophy and techniques. One respondent observes that "It is very difficult to carry out research with farmers," while recommending that new techniques developed through traditional research methodologies be disseminated to farmers by demonstrations on commercial farms. Others acknowledge problems with record-keeping and control or reporting of variables in on-farm research, but believe it important to continue and strengthen such research nonetheless.

Some respondents are primarily education-oriented. Organic farmer organizations seem particularly concerned with sharing information about specific techniques and practices among members through newsletters, conferences, field days or demonstrations.

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They perceive a lack of university or extension service support for organic farming, and a consequent need to turn to one another in developing workable, economically viable systems. About half of the respondents specifically noted either hostility or lack of support for alternative practices from universities or extension services.

While none of the respondents is narrowly focused on groundwater contamination, all indicate a concern for groundwater issues. All agree that prevention of groundwater contamination, rather than clean-up programs after the fact is the necessary focus of effort. They further agree that prevention involves reduction (or elimination) of agrichemical use. While agriculture and agrichemicals are their primary focus (as well as the focus of this survey), they are also aware of the contamination of groundwater attributable to industrial chemical use and to urban residential use of agrichemicals.

Their further shared concern is for the future of farming. Most of the respondents address the form of farming, and one-third specifically state that there is an integral connection between concern for water, air and soil and commitment to smaller scale, non-conventional family farming. Two-thirds assert that reduced agrichemical use must be made economically feasible and economically sustainable for farmers.

III. Problem and Causation

All respondents said that they were familiar with some kind of problem of agrichemical contamination of groundwater. Their descriptions of the problem existing in each of their specific areas and of their sources of information vary widely.

A California organization lists a wide variety of contaminants found in its area: DBPC, aldicarb, dimethoate, EDB, endosulfan, aldrin, simazine, undane, DDT/DDE/DDP, atrazine, chloradane, heptachlor, dicofal, bromacil, 1,3-D, carbofuran, 2,4,5-TP, alachlor, zylene, chlorothalonil, diazinon, 2,4-D, endrin, dichlorobenzene, PCP, ordram, tetrachloroethylene, toxaphene, and nitrates.[3]

On the other side of the country, a Northeastern group reports that some pesticides have been found in golf courses by the EPA, that a "groundwater survey" has found "some spots" where NO3-N levels are approaching 10 ppm, and that there are reports of Alachlor presence and high nitrate levels in some wells.[4] While characterizations of the type and extent of groundwater contamination vary, only one of twenty-nine organizations reports that in its area there is "no serious problem yet" with groundwater contamination.[5]

While numerous surveys are cited by respondents as sources for their information, most of these seem to be select, problem-area studies, not comprehensive regional water-testing surveys. That is, studies have been done where a problem is perceived. Baseline studies which establish the condition of groundwater in an entire state or region are rare. In fact, as the United States Geological Survey reports, the national status of ground-water contamination from toxic chemicals and organic substances is uncertain at present because of a lack of consistent data.[6]

This gap in research allows a continuing public perception of groundwater contamination as a limited problem, and one mostly occurring "somewhere else." One exceptional case may be California, which has recently passed legislation requiring statewide well testing. That program has not been fully funded.[7]

Respondents generally agree on characterization of the causes of agrichemical contamination of groundwater. Not surprisingly, they believe that chemical contamination of groundwater is a direct result of chemical applications. This happens through the practice of conventional agriculture, defined as those systems and practices tending to 1) have a high degree of specialization, 2) emphasize high yields, and 3) achieve those yields through use of major inputs of agrichemicals and other off-farm purchases.

Conventional agriculture, however, is widely accepted as the norm for agricultural practice. Specialization is promoted by government programs. Most university research still singlemindedly aims to increase production. Use of capital (off-farm inputs) to replace intensive agricultural labor is considered progress in freeing farmers from the dawn-to-dusk toil of their grandfathers' era.

High inputs of chemicals -- fertilizers, pesticides, herbicides -- are necessary to boost production in a paradigm which presumes both mono-cropping and less-intensive labor inputs. Both pesticides and nitrates end up in the groundwater as contaminants. Yet even in conventional agriculture, farmers can reduce chemical use. For example, recent Iowa studies[8] focus on reducing both costs and groundwater contamination by discovering lower, optimal rates of application for nitorgen.

Respondents challenge various parts of the conventional agriculture paradigm. Almost all see a problem with present levels of agri-chemical inputs. About forty percent see the entire conventional agriculture model as problematic. They maintain that the push for higher production, over-specialization, loss of livestock on the land, and substitution of chemicals for human labor are all part of a larger problem. For the latter group, groundwater contamination is a symptom that cannot be resolved in isolation from the larger problem of the United States agricultural system.

IV. Proposing Solutions

The types of solutions suggested as appropriate vary according to perceptions of the causes of groundwater contamination. As noted in the preceding section, some respondents focus on reduction of specific groundwater contaminants. Others challenge the entire agricultural system and believe that contamination of groundwater is a significant part of a larger, systemic problem.

For purposes of this discussion, individual techniques recommended as partial or entire solutions are called "farming practices." Complexes or combinations of farming practices which are advocated as part of a larger change to a new agricultural system are referred to as "farming systems."

Some of the respondents focus research and/or information dissemination on specific farming practices. Others advocate systemic change and may believe that a primary focus on individual farming practices is short-sighted or counter-productive. With only one exception,[9] even advocates of systemic change generally report their research in terms of individual farming practices.

The specific farming practices most frequently listed by respondents are summarized and described below. (They are described in detail in a chart on page ___.) Use of any one or more of these practices could result in reduction of use of agrichemicals.

- ***Animal manure:***[10] Current research focuses on the best use of animal manure as a substitute for commercial nitrogen. Studies focus on questions such as collection and storage of animal wastes, run-off from storage sites or from fields, composting, time of application, and manner of application.

- ***Cover cropping,***[11] use of ***green manures,***[12] and ***intercropping:***[13] Almost all respondents doing any research report research on one or more of these techniques. One example is "intercropping of legumes and grains to test crop complementarity and for improved nutrition for livestock hay and pasture."[14]

- ***Tillage:***[15] Some issues currently being researched include comparison of the out-of-pocket costs for gasoline, machines and labor in tillage for weed control with the out-of-pocket costs for chemical purchases, gasoline, machines and labor in herbicide-oriented systems; effectiveness of various methods of tillage; and combination of tillage for weed control with reduced levels of herbicide application or with herbicide application only on specific problem areas.

Respondents also report experimentation with various types of tillage equipment, such as harrows, rod weeders, rotary hoes, etc.[16]

- ***Composting and mulches:***[17] Some respondents report use of mulches to prevent water loss, thus reducing the need for irrigation as well as reducing run-off. Mulches are particularly significant on smaller acreages intensively cultivated for production of fruits and vegetables. Some mulches can also add nutrients to the soil, and can discourage weed growth.

Respondents report research on composting as a way of reducing groundwater contamination from waste disposal and as a way of generating soil-building organic matter and fertilizers. Research on composting is widespread, ranging from city-wide leaf composting projects in urban areas to back-yard compost heaps for disposal of kitchen wastes and garden fertilization to composting of animal manures on dairy farms.

- ***Crop rotation:***[18] Research focuses on issues such as optimal sequence of rotation and favored crops for a given region.

- ***Soil testing:***[19] Respondents report soil testing as an important component of research on many of the other practices described. Soil testing for nitrogen, for instance, is used to reduce the amount of commercial nitrogen applied in conventional agriculture.[20] It is also used in research on the most effective times and methods of applying animal wastes and on the usefulness of various cover crops and rotations in building nitrogen in the soil. Proper timing and placement, cued by soil testing, can reduce the amount of fertilizer applied, and can also aid in reducing run-off.

- ***Plant allelopathy:***[21] Rye is most frequently cited as a cover crop which has chemical properties useful in controlling weeds.[22] When it is tilled into the ground it appears to inhibit the growth of some common weeds. Walnut leaves are reportedly a useful herbicide.[23]

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- ***Biological pest and weed controls:***[24] Biological weed controls are in earlier stages of research and development. Biological controls are used more on smaller acreages.

- ***Pest scouting:***[25] One respondent cites the need for improved farmer education on pest identification and pest life cycles in order to monitor the presence of insect pests.[26] Integrated pest management programs obviously depend on proper identification of both pests and beneficial insects present in a given field or farm.

- ***Weed flaming:***[27] One respondent reports research on weed flaming. Other innovative technologies for weed control include electric shock weeders and a "weed wringer" to pull weeds standing above the crop canopy, and sun solarization by use of black plastic mulches.[28]

Different crops and different farming operations can utilize various combinations of these practices. Few farms are likely to use all of them. How they are chosen and combined depends only in part on external factors such as the climate and geography or markets available to the individual farm. Another significant factor in choosing specific combinations of farming practices is the philosophical orientation shaping the farm's structure -- the farming system.

In discussing farming systems, various respondents used terms including conventional agriculture, sustainable or regenerative agriculture, organic farming, low-input agriculture, diversified farming and family farming. Some definitions or descriptions of these terms will be helpful in understanding the overall systemic approaches advocated.

- ***Conventional agriculture*** may be defined as those systems and practices tending to 1) have a high degree of specialization, 2) emphasize high yields, and 3) achieve those yields through use of major inputs of agrichemicals and other off-farm purchases.

- ***Sustainable*** or ***regenerative agriculture*** is frequently contrasted with conventional agriculture. Sustainable agriculture includes those systems or practices that are compatible with biological and physical conditions and that support and prolong the contributions of natural resources to the provision of goods and services for human consumption, while providing economically viable returns for farmers using such systems and practices. Oregon Tilth's statement of purpose contains what might be a shorthand description of sustainable agriculture as "environmentally sound and socially equitable."[29]

- ***Regenerative agriculture*** is a preferred term for many who believe that the environment has been so severely damaged by conventional agriculture and by industrial practices that it must be regenerated or restored, not merely sustained in its present condition.

- ***Organic farming*** is a term of art as well. Some states have passed legislation which defines what kinds of agricultural practices may be classified as "organic" and what types of produce may be sold as "organic." The California Organic Food Act, for example, provides that "organic" means foods which meet the following requirements.

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> (1) Are produced, harvested, distributed, stored, processed, and packaged without application of synthetically compounded fertilizers, pesticides, or growth regulators.
> (2) Additionally, in the case of perennial crops, no synthetically compounded fertilizers, pesticides, or growth regulators shall be applied by the grower to the field or area in which the commodity is grown for 12 months prior to the appearance of flower buds and throughout the entire growing and harvest season of the particular commodity.
> (3) Additionally, in the case of annual crops and two-year crops, no synthetically compounded fertilizers, pesticides, or growth regulators shall be applied to the field or area in which the commodity is grown for 12 months prior to seed planting or transplanting and throughout the entire growing and harvest season for the particular commodity.[30]

In any state, organic farming systems will certainly eschew the use of most agrichemicals. Some states require even longer time periods of chemical-free farming to earn certification of produce as organic.[31]

- ***Low-input agriculture***, on the other hand, means reducing the use of agrichemicals. This is a term frequently used by those who wish to avoid the stringent non-use commitment associated with the term organic. Low-input is a term more attractive to farmers who want to reduce their reliance on chemicals but are unwilling to give up their use entirely.

Farmers who use chemicals commonly see "organic" farmers as highly ideological. They may be uncomfortable with a position which begins by denouncing chemicals as harmful, and are more comfortable talking about chemicals as too expensive or as overused.

Several respondents cite such attitudes as a problem which must be faced. Respondents generally do not share these attitudes toward organic farming, but cite them as problems in education and

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promoting change of farming practices. On the other hand, one reviewer noted that some conventional farmers view organic practices favorably because of premium prices paid for organic produce.

- ***Diversified farming*** refers to farms which raise a variety of plants and animals. It is marked by the inter-dependence of the animal and crop production systems. In this way it differs significantly from the specialization of conventional agriculture.

- ***Family farming*** also generally emphasizes diversification. It differs slightly in placing primary emphasis on the role of families in caring for land and passing it down from generation to generation. Care for the land or, more strongly, love of the land, is seen as primary in preventing damage to the land and contamination of the water.

V. Research: Progress and Problems

Respondents were asked to list specific practices which they had researched during the past two years. Eighteen categories were suggested, and space was provided for description of other types of research which did not fit within these parameters. More than one hundred research projects falling within the suggested categories were reported and sixteen "other" types of research were described. Twenty-three of twenty-nine respondents reported that they conducted some type of research.

The research projects do not lend themselves to easy numerical analysis. Many projects involve assessment of multiple practices. A respondent might report research in the areas of surplus fertilizer/manure handling, composting, water conservation, and tillage for weed control. While the survey summary records this as four separate projects, the research might actually be one integrated project. On the other hand, some organizations report several farmers simultaneously engaged in similar or identical research, such as research on tillage for weed control.

Further, respondents have differing perceptions of what constitutes research. Some engage in traditional, "scientific" research with randomized, replicated test plots and careful control of variables. One respondent seemed dubious about the possibility of any other kind of research:

> It is very difficult to carry out research with farmers. Demonstrating new techniques on commercial farms is a viable and tested method of disseminating information. I think your questionaire confuses research and demonstration.

Another criticized the emphasis of traditional research, saying:

> I wish we could get researchers more involved with practices that are being developed by farmers. Research and Extension have their on-farm trials, but these are to demonstrate what they have already done on the experiment station. Many of the most practical and effective practices are actually originating with farmers.

This split between traditional, university-style research and new, farmer-designed and farmer-conducted research points toward development of a new model for research. The new model locates research on the farm rather than in the laboratory. Research is designed and conducted by farmers rather than being the exclusive possession of scientists. It is holistic, considering the entire farm or field system rather than attempting to isolate only a single variable for study. It is ecologically focused, looking at the impact of farming practices on the entire ecosystem, rather than focusing narrowly on enhancing production. The new model communicates its results via newsletters, field days, demonstrations and farmer-to-farmer contacts rather than through publication in refereed journals.

But the new model of research does not necessarily replace the old and may be a valuable addition to university-conducted research. Neither type of research is without problems. In order to get a sharper picture of the varieties of private, non-profit involvement in research, three examples are reported here. The first, from a well-funded research farm, is an example of traditional research. The second, from a farmer organization, illustrates the advantages and the pitfalls of the new model of research. The third example, also from a farmer organization, combines traditional and on-farm research.

Clagget Farm

The Claggett Farm is a project of the Chesapeake Bay Foundation in Maryland. The Foundation's objectives are "to promote wise management of the Chesapeake Bay; to be an advocate for the Bay's Natural Resources." The Farm is one small segment of the overall Foundation operations, employing five of the Foundation's 75 employees. The Farm budget is approximately $230,000 annually.

Research projects on the Farm include the use of hairy vetch and crimson clover as green manures; intercropping, including drilling soybeans into wheat/barley and overseeding legumes in corn; tillage for weed control, including comparisons of rotary hoeing, ridge tillage, no till and conventional systems for corn and beans;

and demonstration projects using crop rotations, use of livestock wastes and cover crops.

One of the more traditional research projects is the tillage comparison project carried out in cooperation with the Environmental Protection Agency and the University of Maryland. This project compares ridge-till, no-till and conventional planting for corn and soybeans. Nineteen different treatments include combinations of the tillage systems with no herbicides, banded herbicides, and broadcast herbicides. The project will run five to seven years, and focuses on economic comparisons and weed control, measuring changes in number and species composition of weed populations.

Another cooperative project with the University of Maryland compares a low-input system for corn, wheat and soybeans with an agrichemical system. This project involves twelve plots, each measuring twelve by thirty meters, all farmed with four-row farm equipment. The plots are monitored for surface runoff and leachate.

These research projects seem fairly traditional. They use multiple replications under close supervision of university researchers. Farmer input comes from advice from one local farmer, who is salaried half-time to work with the project. A portion of the farm involved is used for research. Another portion is farmed by a tenant on a cropshare basis. Each project focuses on a fairly narrow range of variables. The results of the research should be publishable, replicable, and highly credible by almost any standards.[32]

California Clean Growers Association

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California Clean Growers Association is a membership-supported organization with no paid staff. It was organized, and its work began in 1987. Like many smaller organizations, its research work is centered around the volunteer efforts of its founder, Paul Buxman, with assistance from a limited number of other member-farmers. Its 1988 budget was $2,000.

California Clean Growers Association objectives are "to reduce dependence on chemicals; to farm in the cleanest way possible so as not to pollute water, air, or soil; to create farm environments which encourage predator activity, increase organic matter in our soils, and beautify our surroundings."

Research activities listed by California Clean Growers include soil or plant tissue testing, fertilizer placement, crop rotations, green manures, livestock wastes, cover crops, tillage for weed control, mulches or composting, plant allelopathy, biological pest/weed controls, irrigation management for water conservation, surplus fertilizer/manure handling, harvesting methods to reduce bruising of fruit, return of crop wastes to the orchard of origin, use of vegetable oil for scale control, and use of sulfur for powdery mildew control.

The organization says that twenty farmers advise on research projects, ten conduct on-farm controlled experiments and five conduct on-farm demonstrations.

One of the research projects reported is mealy bug control in grapes without chemicals. It is reported as follows:

> Mealy Bugs have shown resistance to most pesticides since 1986. Fred Smeds, whose mealy bug infestation has worsened

> each year since 1985, tried not spraying a ten acre block with any pesticide. A natural predator of mealy bug moved in and cleaned up virtually every pest. Fred estimates a 20% infestation prior to the experiment. It appears that mealy bug problems are a chemically induced problem.[33]

Another research project was conducted in cooperation with the University of California's Kearney Field Station. This project, Sex Confusion of Oriental Fruit Moths, is described below:

> Pheromones resembling those created by the female OFM are synthetically produced and placed in slow-release dispensers. These are hung in each tree. The male OFM cannot find the female, thus her eggs are not fertilized and do not hatch. Kearney Field Station used peaches, plums and nectarine crops for the trial orchards. in order for these tests to be valid, the farmer must be willing to leave [the] complete orchard unsprayed. That's where the Calif. Clean Farmers come in. After two years, the pheromone strips have proven themselves very effective.[34]

A third experiment involved control of powdery mildew with sulfur only through leaf thinning. Paul Buxman, director of California Clean Growers Association, reports:

> This project was meant to see if Ruby Seedless Grapes could be grown without fungicides. It was tried on six acres for two successive years. Only partial success so far. We will try altering our sulfur application times. I intend to experiment with this field for the next ten years.[35]

Based on these descriptions, the research projects seem to fit the new model of on-farm research. They do not necessarily use multiple replications, and not all are supervised by university-certified researchers. Farmer input is the primary determinant in project design. The farms involved must provide the economic support of the researcher-farmers. Each project does focus on a fairly narrow range of variables. But, unlike more traditional research, not all projects use control plots. The general idea is finding workable, low-input solutions to existing problems -- not demonstrating the truth or falsehood of hypotheses about, for example, sulfur and powdery mildew.

Similar research is reported by other organizations. The Maine Organic Farmers and Gardeners Association, for example, reports weed control research designed to compare the effectiveness of straw, sawdust and living oats as mulches in raspberries.[36]

The results of the California Clean Growers Association research are probably not publishable in refereed journals. But publication is not the goal. Rather, results are communicated through the organization itself.

> Every two months we meet at different farm sites and the owner speaks about his farm practices which have helped eliminate inputs. ...
> We publish quarterly our newsletter which details our experiments.
> We list all farmers by crop so they can stay in touch with farmers experiencing similar problems. Growers lists are handed out to all members with phone numbers and crops grown.[37]

Practical Farmers of Iowa

Practical Farmers of Iowa is a farmer organization which had no paid staff and little funding in 1988, but will be foundation-funded for $100,000 in 1989. Research projects included twenty-three farmers conducting on-farm controlled experiments in 1988. Practices researched included soil or plant tissue testing, fertilizer placement, fertilizer timing, crop rotations, livestock wastes, cover crops, tillage for weed control, composting,

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biological pest/weed controls, and economic assessments on all trials.

All of the Practical Farmers' research is conducted on-farm, by farmers. The research, however, aims to be credible to the traditional research community.

> On-farm, farmer-conducted field trials of sustainable agricultural practices [are conducted.] The nature of the trials is determined by the farmer. Themes generally are: fertilizer reduction, weed control without herbicides, and winter cover crops. Each trial has only two treatments: the farmer's customary practice and an alternative practice. The treatment pairs are randomized and replicated six times at each site. Treatment strips are one or two implement-widths, and they run completely across the field. This makes it possible to simultaneously farm and conduct the trial.[38]

The Practical Farmers report some difficulties with their research model, particularly in the areas of record-keepng and field trial layout. Also, some farmers "get in a hurry at harvest and bulk the treatment strips together," making assessment of results difficult.

But this organization looks forward to improving research effectiveness and credibility, while keeping their research farmer-directed and farm-centered. Grant funding will enable employment of a full-time on-farm trials coordinator as a liaison between farmers and non-farmer researchers. Scientific input is sought in order to obtain "a more detailed understanding of the processes involved." Practical Farmers of Iowa intends to combine the best of the traditional and new models of research.

In this endeavor, it has cooperated with the Rodale Institute, a much larger organization firmly committed to on-farm research.

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Rodale's mission statement includes "synthesiz[ing] this research into information products and services that are practical and beneficial to our audiences ..."[39] This kind of orientation to practical application of research and clear communication of research to farmer constituents is a common theme of many respondent organizations.

Research Directions

While farm-centered research is praised by many of the respondent organizations, the drawbacks are also noted. Farmers have many constraints on their time, are usually not paid for research, and may place a higher priority on getting a crop harvested than on recording and reporting results. For all of these reasons, and because participants frequently lack academic credentials, results of farm-centered research are less credible to the academic and funding communities and less likely to be publishable in refereed journals.

On the other hand, farm-centered research is more likely to be accessible to other farmers in the area, and more likely to be perceived by them as credible and relevant to their own operations.

Despite specific criticism of universities and extension services by many respondents (see Table V), there seems to be a consensus that more research and more involvement by university researchers is required to deal with the problem of groundwater contamination. On the other hand, most respondents do not expect or want universities to conduct research without farmer input, direction, and involvement. Private non-profits and their farmer constituents and members see themselves as integral to research and development of solutions to this problem.

The single obstacle to research cited most frequently by respondents was funding. The response of one organization is a representative summary of the research problems listed:

> (1) inadequate financial support by federal and to lesser extent state governments;
> (2) farmers unwilling or unable -- due to space, cost (dollars) or inconvenience -- to commit resources necessary for randomized, replicated, repeated research (i.e. good research);
> (3) bias [against] small, nonprofit, alternative organizations by land grant colleges;
> (4) farmers' time availability;
> (5) too much money spent on studying symptoms and biotechnology and not enough on short-term development of methods.

Other respondents pointed out that farmers are not paid to experiment; that, unlike university researchers, they bear the cost of crop losses on control acreage; and that they may not have the skills or inclination to do thorough data collection.

Most respondents see solutions to these problems in increased funding for work with farmers in on-farm research -- not in removal of research from farms to laboratories and experiment stations. Typical is AERO's support of "joint research projects with equal participation by grassroots, farmer-based organizations."[40] At least two respondents advocate use of a research coordinator who is familiar with traditional research design and data collection and who is capable of working and talking with farmers.

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In addition to the changes in research design and methodology discussed above, respondents report the need to change the direction of research. They characterize the current direction of government and university-funded research as support of conventional agriculture, focused on bigger farms and increased production. One respondent points to the fascination of some researchers with patents, biotechnology, academia, pure science, large farms, and "successful farms," to the exclusion of research and development and concern for ecological impacts.

Some of the gaps identified as requiring further research are non-chemical methods of weed control; role of soil microbes in maintaining fertiilty; dynamics of pest-predator relationships; reduced tillage; low-tech methods for cultural control of weeds and insect pests; localized information on specific practices such as timing of planting, types of legumes, timing of mowing or plowdown of green manures, use of mulches on ridges; et cetera. In short, the research respondents believe is most necessary to address groundwater contamination problems centers around methods which make low-input farming profitable in a variety of farms and locations.

VI. Educational Efforts

All respondents reported involvement in some educational programs. Programs ranged from appearances on television programs to sponsoring farmer-to-farmer referral and telephone networks to field days and meetings or conferences. Field days, meetings and publications were the educational activities used most frequently. Media (television, radio, newspapers) appearances for publicity and

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farmer-to-farmer communication programs were also used by two-thirds of the respondents.

A few examples will illustrate the diversity of the information dissemination activities listed by respondents:

- Claggett Farm sponsors a general education program focusing on agriculture's relationship to the Chesapeake Bay. Its audience ranges in age from sixth grade to adult, with the majority at a high school age level. About 4,000 visitors to the farm participate in the program each year.

- The Northern Plains Sustainable Agriculture Society has published a booklet on "Switching to a Sustainable System." Written for farmers, it describes some of the pitfalls to watch out for when trying to reduce the chemical dependency of a farming system. Rather than advocating a specific ideology, the booklet points out that "Sustainable farming is a continuum, with several entry points and different end points, depending on a farmer's management skills and farm resources."

- Practical Farmers of Iowa sponsors field days on sixteen of twenty-three farms participating in research projects. In addition, they hold winter meetings, cooperators (farmer-researchers) meetings, and other conferences and meetings, and use local farmer members for farmer-to-farmer referrals.

Respondents differ on the effectiveness of current educational programs, the problems encountered in information dissemination, and the gaps in farmer education. The Wisconsin Rural Development Center offered the most optimistic assessment of the state of information dissemination:

> No real problems ... we're noticing that the groundwater contamination issue is becoming a major topic of discussion in this state, at all levels. The debate appears reasonable and well-informed, and farmers using low-input techniques are no longer considered odd or fringey.[41]

At the same time, a warning is in order:

> There still needs to be more farmer-to-farmer contact on disseminating reduced-chemical farming techniques. All the extension bulletins in the world won't close that gap.[42]

The Center is already working with one farmer research network in five counties, and plans to set up another in another part of the state. While its view of the state of information dissemination is more sanguine than that of many other respondents, its preferred method of education is the same -- farmer-to-farmer, on-farm, in-the-field research and demonstration.

Some other respondents take another position on the present state of information dissemination. One states that the "vast majority of farmers believe groundwater contaminating chemicals are essential to successful farming." Others observe that there is a simple lack of information and lack of research on the causes and prevention of groundwater contamination.

The problems respondents identify in the area of education or information dissemination fall in two general areas: unavailability of reliable, tested information about low-input techniques and persistence of stereotypes about reduced input farming. Of course, one cannot disseminate information which does not yet exist -- that gets back to the gaps in research cited above.

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But the other problem of stereotypes of low-input farming or organic farming or reduced chemical use is also widespread.

> The extreme ... lack of understanding of what organic means. It is not a return to the horse and buggy but a system of increased management to take the place of the quick fix mentality of current agriculture.
>
> Lack of cooperation from the extension service on positive, alternative methodology.
>
> The biggest problem I face is a lack of trust on the farmers part. They believe that if one wants to see a reduction iun pesticide use that you must be anti-agriculture. [There is] little or no education at the university level on non toxic farming methods. Everyone graduates programmed for high input farming.
>
> [Problems are] stereotypes about reduced-input farming. Sometimes these are promulgated by local extension agents. The major misconception is that there is an economic sacrifice to be made when a farmer switches to ecologically-sound methods.
>
> The largest gap seems to be in the area of transition from high tech/chemical farming to sustainable farming practices. Farmer education, in general, doesn't seem to be directed much to small/family farmers (which includes many minority peoples) -- indicating an economic and political gap. [We also experience] the difficulty of translating technical information into easily uderstood language that is culturally relevant to the farmers in our region who are Hispanic and Native American.

As these comments indicate, many respondents share a frustration with land grant universities and with extension services. They perceive the conventional agricultural education system as geared primarily to conventional agriculture -- meaning high chemical inputs which contribute to groundwater contamination.

They are frustrated with the tendency of extension services to continue to push high-input agriculture and to look on low-input methods as eccentric and uneconomic.

Often the private, non-profit organizations feel that they offer the only real educational alternatives for farmers in their areas. They are frustrated by lack of funding for their own efforts, and by what they perceive as only token attention paid to low-input agriculture by the agriculture education "establishment:"

> The gap (in farmer education on groundwater contamination) is almost as big as California. Except for our organization and a few smaller efforts by other private groups, there is virtualy no information available to California farmers on viable nontoxic alternatives. The U[niversity of] C[alifornia] system is a joke. Our organization spends almost as many hours on these areas as the entire 5,000 person UC system does! The Sustainable Ag Program at UC Davis has a <$400,000 annual budget. The UC Ag System has a $181 million budget! [Emphasis in original.]

Despite strong criticism, the private, non-profit organizations do not advocate abandoning the extension service or the universities. They are frustrated with present performance, but express a great need for the research and resources of these institutions. One way of summarizing their position is to say that education must begin with re-education of the certified educators -- the universities and extension services. But more than a change of heart is needed. Once the direction of research and education is changed there is still a "forty-year backlog of research" on low-input practices to be tackled.

It should also be noted that not every respondent shares the general frustration with traditonal agricultural education. Some

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have established close and satisfactory working relationships with land grant institutions, extension services, and government agencies. Some respondents name specific individuals within various universities who have been particularly helpful. Once a close working relationship has been established, universities have both monetary and personnel resources which can be brought to bear on cooperative projects. One example is the Nebraska Sustainable Agriculture Society co-sponsorship of a series of winter workshops on sustainable agriculture techniques, together with local extension services.[43]

The relatively new LISA program of the USDA also received high praise from several respondents. LISA is the Low-Input/Sustainable Agriculture research and education program which was established by the Agriculture Productivity Act, part of the 1985 Food Security Act. LISA was not funded until December 1987, when Congress appropriated $3.9 million to LISA to generate and provide reliable informaton on reduced input systems to reduce cost, control erosion, and abate pollution from heavy fertilizer and pesticide use and monoculture cropping systems.[44] LISA is seen as a good first step in the direction of USDA, university, and extension support for low-input agriculture. It is also seen as particularly valuable because its charter mandates cooperation between public and private agencies.

But reviewers from some private, non-profit organizations have reservations about the LISA program. One view is that some land grant researchers have merely reworded previous conventional research proposals to get LISA funds without really integrating LISA concepts into their research planning. While the concept of LISA is seen as valuable, they are concerned that its implementation may not reflect the intent of Congress to reduce inputs and to bring farmers into the research design process.

Even those respondents who are strong critics of land grant institutions recognize that their primary focus on conventional agriculture is not an entirely deliberate choice. In part, research at land grant institutions is driven by the availability of research money. And that has meant research funded in part by the pesticide and fertilizer industries. Because cultural controls of weeds and pests do not generate profits for business in the same way that chemical sales do, research in these areas has not received private, corporate funding.

Because the traditional educators have not focused on low-input methods and systems, other means of farmer education and information dissemination have developed. For the most part, the respondents favor direct, on-farm contact as a primary means of communicating about alternative methods and practices. When farmers can try out new methods with some technical and moral support, when they can adapt the methods to their particular farms and fields, when their neighbors can observe the daily growth of crops or weeds on research strips -- then low-input alternatives seem less "fringe" and more practical.

Suggestions for "filling the gaps" in farmer education range from the very general -- re-orientation of the traditional sources of information -- to the very specific -- establishment of natural farming hot lines for each crop, education of farmers on the life

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systems and identification of pests, education on proper methods of inoculating legumes, information on specific crop rotations. At the present time, private organizations see themselves as in the forefront of both research and information dissemination about low-input strategies to prevent groundwater contamination. But in the long run, most believe that larger institutions must assume a greater role:

> [Government and state agencies] need to realign their research and education programs to prioritize sustainable agriculture as the highest priority. They need to take on the role of leading farmers into sustainable practices. This means that they should make a value judgment on farming systems. To a large extent, this will involve re-education of many research, teaching and extension staff.
>
> Private organizations have been exploiting the vacuum caused by the lacks in the State and Federal systems. [T]his niche will be present for the next decade at least.

VIII. Policy Recommendations

Respondents were asked to describe what they saw as appropriate roles for federal, state and local government, universities and private organizations in research and education on farming practices which can reduce groundwater contamination. They were also asked for suggestions on specific government programs and practices which could reduce groundwater contamination. While respondents were not unanimous in their positions, their policy responses can be summarized under four general headings:

- support for alternative farming systems (17 respondents);
- changes in commodity programs (11 respondents);
- strengthening conservation policies (15 respondents);
- directions for research and education (20 respondents).

Support for Alternative Farming Systems

With very few exceptions, present government policies at all levels support a conventional farming system based on the premises that "bigger is better" and that increasing profit and productivity are the only legitimate goals of a farming system.[45] Short-term measures and balance sheets are used to measure profitability in the conventional system. Environmental and human costs are not accounted for as part of the expense side of conventional agriculture's balance sheet.

In the long run, this conventional farming is destructive of natural resources and of people. Increasing agrichemical contamination of groundwater is one symptom of its long-term failure. Addressing this symptom without dealing with the entire system of conventional agriculture is not an effective long-term strategy.

Alternative farming systems need to be the focus of research and government support. This means re-directing financial and human resources (price supports, research grants, set-aside funds, etc.) away from support of high-input, large-scale agriculture -- support of production -- and instead focusing on support of farmers who are taking care of the land. Rather than subsidizing production, government expenditures should subsidize conservation or stewardship of natural resources.

Some specific suggestions to move in this direction are:

- tax incentives structured to support investment in alternative methods of agriculture;
- lending policies which encourage crop rotations and crop diversity, rather than mono-cropping;
- get animals back on the land in the Midwest and other grain cropping regions;
- development and promotion of alternatives to commercial fertilizers and pesticides;
- targeted beginning-farmer loan programs to encourage the development of small, labor-intensive, family or multi-family farms.

One respondent noted that "We can ill afford the myopic view that large farmers are the only players in the agricultural field." In the same vein, another suggested land policies which would encourage young people to return to farming.

Changes in Commodity Programs

Respondents were very concerned with pointing out the deleterious overall impact of current federal farm programs and policies. Most of the respondents agree that:

1) Commodity support programs and the 1985 Food Security Act discourage diversification, crop rotation, and low-input methods of production because they are based on payment for productivity.

2) Farm programs and policies do not take into account the long-term ecological costs of high production and high chemical inputs.

3) Even ostensibly environmentally conscious programs like CRP can backfire -- specifically in the incentives to heavy herbicide use found in its set-aside/crop residue provisions.

Federal support and/or subsidy programs should be restructured so that they support sustainable agricultural practices instead of focusing on the support of specific commodities. At present, these programs make conventional agrichemical-dependent agriculture more profitable than alternative, low-input systems:

> A conventional corn/corn/soybean rotation with conventional levels of chemicalinputs was compared with four no-chemical rotations that used clover or clover-grass mixtures. The no-chemical systems seem surprisingly competitive with the conventional system ... The conventional system is dependent on federal price supports to maintain its competitivity and shows itself most competitive under high corn prices and high yields.

> United States commodity programs encourage intensive production of selected crops with high levels of agrichemical inputs through two principal mechanisms. The first is by restricting program payments ot only certain agricultural

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> products. The second is by making payments for many commodities proportional to historical production of the commodity. ...
>
> Consequently, given the coupling of government farm subsidies to production levels of supported crops, there is a strong incentive for farmers to push the intensity of supported crops in rotations toward their biological limits. Similarly, there is a strong incentive to fertilize and apply pesticides for near-maximum yields. In any case, the use of grain intensive rotations generally fosters disease and weed growth which requires heavy use of pesticides simply to prevent yield declines.

No specific farm program legislation was recommended by any respondent. The intentional or unintentional bias of the present federal farm programs toward conventional, chemical-intensive, monocropping agricultural practices was the primary focus of their concern.

Respondents also asked that the federal government begin to provide incentives for farmers who want to make the transition from intensive use of agrichemicals to alternative farming practices that can reduce groundwater contamination. Federal regulation should be structured to encourage such alternative practices and to discourage promotion and use of agrichemical products leading to groundwater contamination. At present farmers do not pay directly for environmental damage, nor are they rewarded for good stewardship of soil and water.[46]

Strengthening Conservation Policies

> "New environmental regulation is only half the policy. ...[T]he price mechanism [should] allow agriculture to internalize the cost of environmental pollution by making it financially possible for farmers to shift to less polluting techniques..."

Respondents agreed that there are presently short-term economic incentives to contamination of groundwater by misuse and overuse of agrichemicals. They see economic mechanisms which will reward farmers for sustainable practices as having primary importance. But some environmental regulations were also recommended.

One way to encourage preservation of groundwater quality is to transform the long-term environmental costs of groundwater contamination into short-term costs of doing business. Some suggestions focused on making a better connection between short-term and long-term costs of chemical use:

- tax agrichemicals at point of sale -- revenues from this tax can be used to clean up after the damages caused by chemicals, thus making those who profit by chemical use pay some of the societal costs which they presently escape;
- make chemical manufacturers bear the entire cost of re-registration by the EPA;
- restrict nitrogen applications without proper pre-plant testing;
- give a workers compensation cost break to farmers who do not use agrichemicals;
- make industry pay the entire cost of hazardous waste collection.

Some suggestions were punitive or restrictive in nature:

- outlaw all use of agrichemicals;
- ban more pesticides;
- tax water-soluble, leachable pesticides heavily.

Finally, other suggestions focused on positive use of regulatory power to encourage beneficial farming practices:

- expand and continue CRP and LISA programs;
- use FmHA easements for water protection;
- require all government agencies to use low-input practices;
- provide incentives for conversion to forage crops, including cost sharing through ASCS of cover crops with positive benefit for preventing groundwater contamination;
- mandate cooperation between the USDA and EPA.

Directions for Research and Education

As indicated in the preceding sections, respondents generally state that a complete revision of research and education priorities of major agricultural education institutions is necessary. Overall, they see a need for a new emphasis on organic and low-input farming. This emphasis, they say, cannot come solely from the private sector, but must be supported by government policy as expressed in the research topics given financial support at land grant institutions.

In conjunction with this change in the direction of research, most recommend changes in methodology. Professors and extension service experts should get back to the farm and communicate directly with farmers. Research results must be delivered to farmers in readily usable form. Moreover, farmers should be involved in research and in directing research. Many new and innovative technologies are being developed by farmers themselves.

Research priorities should include competitive grant programs which will reward small non-profit organizations which have developed close working relationships with farmers and farmer

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organizations. These competitive grant programs should provide funding for research in sustainable agriculture.

A few respondents assert that other countries may have a head start on the United States in research on low-input agriculture. But the results of their research are probably relatively freely available, and U.S. researchers should take advantage of work which has been done in Europe and elsewhere during the past ten years.

Government-supported research (including land grant institutions) should focus on development and testing of products and methods unlikely to be financed by the private sector -- for example, on cultural methods of pest control or fertilization. Research should be aimed at increasing soil fertility without chemicals and at increasing the flavor and nutrition of food produced, rather than simply increasing volume of production.

Education programs also need to be realigned to make sustainable agriculture a priority. The entire United States Department of Agriculture needs to refocus on ecological concerns rather than strictly on increasing production through agrichemical inputs. Public information programs need to be provided at state, regional and local levels.

* * * *

Overall, the policy recommendations made by respondents reflect a conviction that the problem of agrichemical contamination of groundwater cannot be attacked or resolved in isolation from the restructuring of the entire agricultural system. While the organizations themselves frequently focus their research and education efforts on specific farming practices, they also state that these practices need to be implemented as part of a systemic approach which focuses not only on resolving problems of groundwater contamination, but also on significant changes in the farming system.

Non-profit organizations see significant continuing roles for themselves in both research and education. While different organizations describe their roles differently, some significant contributions which they claim are:

- in disseminating the results of research to farmers;
- in informing universities of alternative practices developed and researched by farmers;
- in sponsoring and directing farm-centered research; and
- in pointing new directions for universities, extension services, and policy-makers.

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[4] New Alchemy Institute, survey, p. 2

[5] High Desert Research Farm, survey, p. 2

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[9] Center for Holistic Research Management, survey

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[23] California Clean Growers Association, survey, p. 5

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[26] New Alchemy Institute, survey, p. 12

[27] Michael Fields Agricultural Institute

[28] David Granatstein, Reshaping the Bottom Line: On-farm Strategies for a Sustainable Agriculture, (Stillwater, MN: Land Stewardship Project, 1988), pp. 34, 39; Michael Fields Agricultural Institute, Inc., survey, p. 5

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[29] Oregon Tilth, survey, p. 1

[30] California Health & Safety Code, Section 26569.11(a)(1-3), as enacted by the California Organic Food Act of 1979 and amended in 1982.

[31] Minnesota law requires three years of chemical-free farming for certification.

[32] Clagett Farm, survey

[33] California Clean Growers Association, survey, p. 6

[34] California Clean Growers Association, survey, p. 6

[35] California Clean Growers Association, survey, p. 7

[36] Maine Organic Farmers and Gardeners Association, survey, p. 6

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Glossary

Agrichemicals: Commercial (synthetic) fertilizers and all pest control chemicals and herbicides appied to agricultural lands.

Agrichemical Contamination of Groundwater: Presence of detectable, measurable levels of agrichemicals and their metabolites in groundwater (contamination does not necessarily imply a health risk or other adverse impact).

Agricultural land: Commercial and non-commercial cropland (including market gardens and orchards), forest land, and pastureland.

Animal manure: Can be used as substitute for commercial nitrogen. Prior to the advent of "conventional agriculture's" heavy reliance on purchased inputs, most farms were diversified, raising both livestock and crops. Some crops were raised for animal feed. In turn, the animal wastes were spread on the fields as fertilizer.

Aquifer: zone of saturation sufficiently abundant and permeable to be capable of yielding significant quantities of water to wells and springs, typically transmitting water continuously from areas of recharge to areas of discharge at a rate of a few feet per day. (USGS, 4/84)

Best Management Practices: well-established guidelines relating to cultivation and fertilization, intended to reduce soil erosion, runoff and water pollution, but presuming continued agrichemical use. (Fleming, p. 125)

Biological Controls: deliberate use of natural enemies such as insects and plant diseases to suppress noxious weeds or insect pests. (Granatstein, p. 38)

Conventional Agriculture: those systems and practices tending to 1) have a high degree of specialization, 2) emphasize high yields, and 3) achieve those yields through use of major inputs of agrichemicals and other off-farm purchases.

Cover crops: planted to hold the soil in place rather than leaving it bare from harvest to the next planting. In addition to protecting the soil from wind and water erosion, cover crops may control weeds or improve soil conditions.[1] An example of a cover crop is oats, planted late in the summer or in the fall and tilled under in the spring.

Crop Rotation: deliberately chosen plan of succession of crops for a field and/or farm.

Field Day: tour of farms arranged for purposes of showing the audience (which usually includes a large proportion of farmers) some particular farming practices on each farm.

Green manure: any crop which is planted in order to be tilled into the ground again. Some legumes are used as green manures, in order to fix nitrogen in the soil. As this crop is turned under it decomposes to provide soil nutrients for the benefit of the next-planted crop.

Groundwater: subsurface water that is in a zone of saturation or water that occurs beneath the Earth's surface and fills the voids of the porous earth material or cracks in rocks. (USGS, 4/84)

Integrated Pest Management: systems to reduce pesticide use by using natural enemies of the pest, tillage, crop rotations, and other alternative methods in an attempt to reduce (but not necessarily eliminate) agrichemical use for pest control.

Intercropping: planting two crops in the same field at the same time.

Leaching: movement of water-soluble agrichemicals into groundwater as they are dissolved in surface water.

LISA: Low-Input/Sustainable Agriculture program of the United States Department of Agriculture.

Low-Input Agriculture: complex of farming practices which reduce reliance on agrichemicals and other purchased inputs.

Minimum Till: use of the least possible tillage patterns on a field or farm, e.g. using a chisel plow rather than moldboard plow.

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[1] "Cover Crop Research at New Alchemy Institute: Why, What and How," New Alchemy Quarterly, Fall 1988, p. 3

Monoculture: primary focus on growing a single crop, as opposed to diversification of crops and livestock on a farm.

Nitrate Pollution: presence in groundwater of nitrates, whether from "natural" sources such as animal manure, or from run-off of agrichemicals from fields.

No Till: system of planting grain directly into prior year's stubble, without tillage, typically using high levels of agrichemicals for weed control.

Organic Agriculture: agricultural production without use of any synthetic agrichemicals for any purpose.

Plant allelopathy: the use of various plants in control of either weeds of insect pests.

Reduced Tillage: use of the least possible tillage patterns on a field or farm, e.g. using a chisel plow rather than moldboard plow.

Research Farm: a farm which is managed primarily for research purposes, rather than as an economic unit to provide income for its owners by production of goods for sale.

Ridge Till: building up ridges and planting corn or soybeans directly into these ridges each year, thus reducing tillage of a field and erosion of soil.

Sustainable Agriculture: those systems or practices that are compatible with biological and physical conditions and that support and prolong the contributions of natural resources to the provision of goods and services for human consumption, while providing economically viable returns for farmers using such systems and practices.

Tillage: the basic method of weed control prior to "conventional agriculture's" popularization of large-scale use of chemical herbicides. It substitutes labor inputs for purchased chemical inputs.

Weed flaming: utilizes a boom with a series of propane nozzles to kill weeds.

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Mark Schonbeck, "Cover Crop Research at New Alchemy Institute: Why, What and How," New Alchemy Quarterly, Fall 1988, p. 3

Jean Caspers-Simmet, "New tools to forecast nitrogen use," *Rochester Post Bulletin Agri-News*, 6/30/88

United States Department of Agriculture, "Low-Input/Sustainable Agriculture: Research and Education Program," (Washington, D.C.: United States Department of Agriculture, August 1988)

United States Geological Survey, "Water Fact Sheet: Regional Aquifer Systems of the United States," (Washington, D.C.: United States Geological Survey, April 1984)

United States Geological Survey, "National Water Summary 1986 -- Hydrologic Events and Groundwater Quality," (Washington, D.C.: United States Geological Survey, 1988)

Douglas L. Young and Walter A. Goldstein, How Government Farm Programs Discourage Sustainable Cropping Systems: A U.S. Case Study, Selected paper presented at the Farming Systems Research Symposium, University of Arkansas, Fayetteville, Arkansas, 18-21 October, 1987

List of Respondent Organizations

Name	Address	City	ST	Zip
AERO	44 N. Lost Chance Gulch	Helena	MT	59601
California Certified Organic Farmers	P.O. Box 8136	Santa Cruz	CA	95061
California Clean Growers Association	4399 Ave. 400	Dinuba	CA	93618
California Institute for Rural Studies	P.O. Box 11172	Bakersfield	CA	93389
Center for Holistic Resource Management	P.O. Box 7128	Albuquerque	NM	87194
Clagett Farm	11904 Old Marlboro Pike	Upper Marlboro	MD	21401
Committee for Sustainable Agriculture	P.O. Box 1300	Colfax	CA	95713
High Desert Research Farm	Ghost Ranch	Abiquiu	NM	57510
Iowa Natural Heritage Foundation	1005 Insurance Exchange Building	Des Moines	IA	50309
Kansas Rural Center	P.O. Box 133	Whiting	KS	66552
The Kerr Center for Sustainable Agriculture, Inc.	P.O. Box 588	Poteau	OK	
Land Stewardship Project	512 W. Elm	Stillwater	MN	55082
Maine Organic Farmers	P.O. Box 2176	Augusta	ME	04330
Meadowcreek Project		Fox	AR	72051
Michael Fields Agricultural Institute	3293 Main Street	East Troy	WI	53120
Nebraska Sustainable Agriculture Society	Box 736	Hartington	NE	68739
New Alchemy Institute	237 Hatchville Rd	East Falmouth	MA	02536
Northern Plains Sustainable Agriculture Society	Rt. 1 -- Box 73	Windsor	ND	58424
Ohio Ecological Food and Farm Association	65 Plymouth St.	Plymouth	OH	44865
Oregon Tilth, Inc.	P.O. Box 218	Toalatin	OR	94062
Practical Farmers of Iowa	R.R.2--Box 132	Boone	IA	50036
Rodale Institute	222 Main Street	Emmaus	PA	
Rodale Institute-Arkansas		Fox	AR	72051
Seneca Trail RCD	2 Park Square	Franklinville	NY	14737
Sunny Valley Foundation	4 Sunny Valley Ln	New Milford	CT	06776
Virginia Assn of Biological Farmers	P.O. Box 252	Flint Hill	VA	22627
West Stanislaus RCD	P.O. Box 573	Patterson	CA	95363
Winrock International	R.3 Petit Jean Mountain	Morrilton	AR	72110
Wisconsin Rural Development Center	P.O. Box 504	Black Earth	WI	53515

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Table II

Agricultural Activities/Farm Size

(Respondents were asked to state major agricultural activities and typical farm size in their area.)

Organization	Cash grain	Mixed livestock	Vegetable fruit	Dairy	Other	Farm sizes (acres)
AERO	x	x				no response
CA. Certified Organic Farmers			x			50-60
CA Clean Growers	x		x		x	80
CA Institute for Rural Studies	x		x		x	no response
Ctr. for Holistic Resource Management						
Clagett Farm	x	x	x	x	x	no response
Committee for Sustainable Ag.	x	x	x			1-5000
High Desert		x				<50
IA Nat. Heritage	x	x				290
Kansas Rural Ctr.	x	x				160-2000
Kerr Center	x	x				180
Land Stewardship	x	x		x		300
Maine OFGA			x		x	3-20
Meadowcreek					x	no response
Michael Fields	x	x		x		200-3000
NE Sustainable Agriculture Society	x	x		x	x	200-5000
New Alchemy			x	x		100
Northern Plains	x	x				1000-1500
Ohio EFFA	x	x	x			200-1000
Oregon Tilth		x	x			10-500
Practical Farmers	x	x				no response
Rodale						
Rodale - Ark.	x	x	x	x	x	100-1500
Seneca Trail						
Sunny Valley			x	x		296
VA Association of Biological Farmers		x	x	x	x	no response
West Stanislaus	x		x			1-1000+
Winrock	x		x		x	295
Wisconsin Rural Development Center	x	x	x	x		200-1000

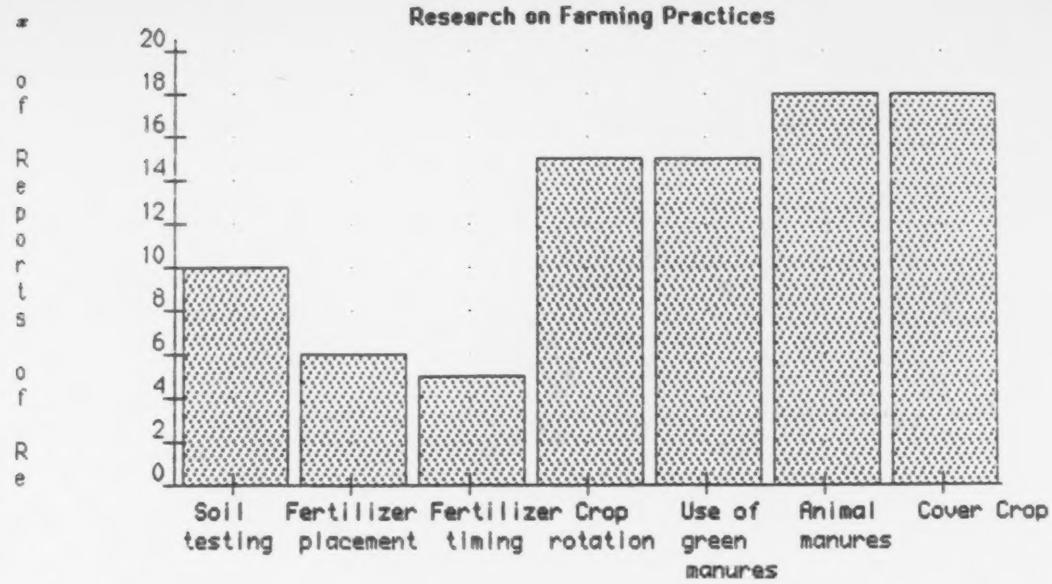
table III
Staffing Patterns of Respondent Organizations
(range of FTE size reported: 0-200)

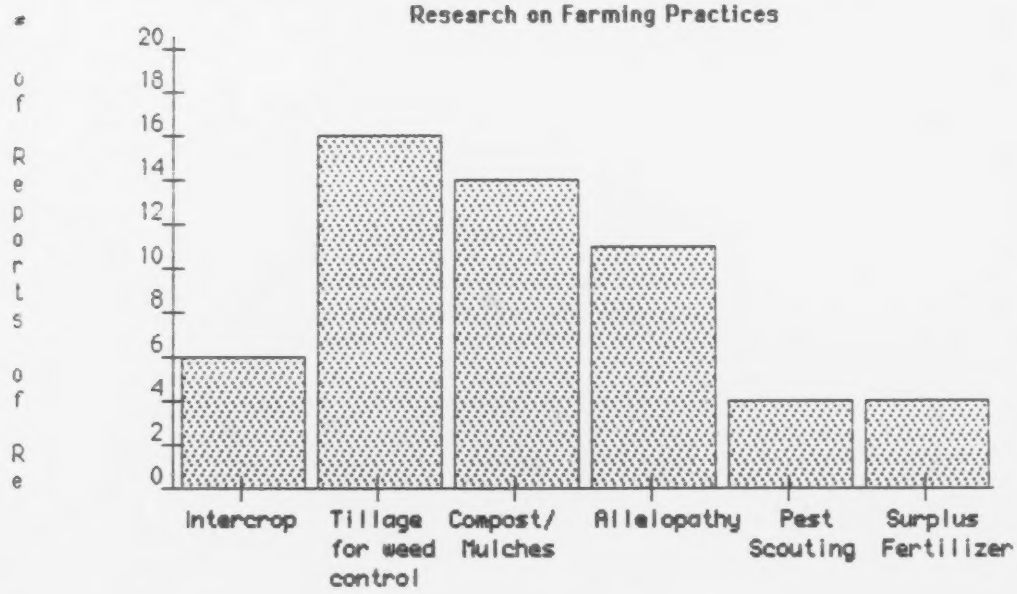
Organization	All Volunteer	1-3 FTE	4-8 FTE	9+ FTE
AERO		x		
CA. Certified Organic Farmers		x		
CA Clean Growers	x			
CA Institute for Rural Studies			x	
Ctr. for Holistic Resource Management				x
Clagett Farm			x	
Committee for Sustainable Ag.		x		
High Desert		x		
IA Nat. Heritage				x
Kansas Rural Ctr.			x	
Kerr Center				x
Land Stewardship				x
Maine OFGA			x	
Meadowcreek				x
Michael Fields			x	
NE Sustainable Agriculture Society		x		
New Alchemy				x
Northern Plains	x			
Ohio EFFA	x			
Oregon Tilth	x			
Practical Farmers	x			
Rodale				x
Rodale - Ark.		x		
Seneca Trail		x		
Sunny Valley				x
VA Association of Biological Farmers	x			
West Stanislaus	x			
Winrock				x
Wisconsin Rural Development Center			x	
Total by category	7	7	6	9

Table IV
Budgets of Respondents

(Range of annual budgets reported: $2,200-$32,000,000)

Organization	$50,000 or less	$50-100,000	$100-600,000	$600,000+
AERO			x	
CA. Certified Organic Farmers			x	
CA Clean Growers	x			
CA Institute for Rural Studies			x	
Ctr. for Holistic Resource Management				x
Clagett Farm			x	
Committee for Sustainable Ag.			x	
High Desert	x			
IA Nat. Heritage				x
Kansas Rural Ctr.			x	
Kerr Center				x
Land Stewardship			x	
Maine OFGA	not reported			
Meadowcreek			x	
Michael Fields			x	
NE Sustainable Agriculture Society		x		
New Alchemy			x	
Northern Plains	x			
Ohio EFFA	x			
Oregon Tilth	x			
Practical Farmers	?			
Rodale				x
Rodale - Ark.		x		
Seneca Trail	not reported			
Sunny Valley				x
VA Association of Biological Farmers	x			
West Stanislaus	x			
Winrock				x
Wisconsin Rural Development Center			x	
Total by category	7	2	11	6





Farm Practices Researched -- Chart, page 56

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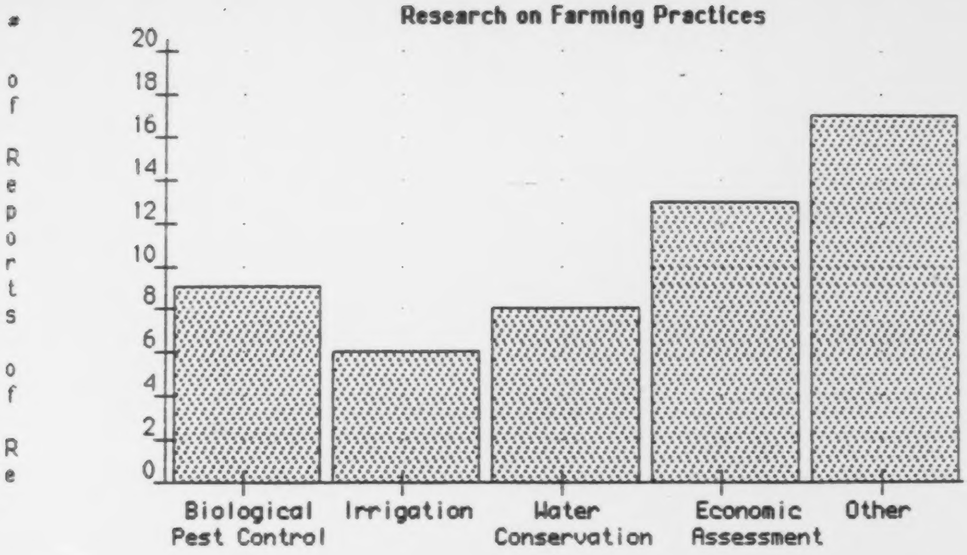

Part of the survey asked organizations to report research on eighteen specific farming practices. These three charts show the reported frequency of research undertaken on these farming practices. The vertical axes represent the number of times organizations reported researching each practice.

Examples of the "other" practices listed by organizations as topics to be researched are flaming weeds in rows, returning crop wastes to orchard of origin, ~~and~~ use of vegetable oil to combat scale. The survey also included the category of "on-farm chemical handling and storage" but no respondents reported research in this area.

Methods Used in Information Dissemination/Farmer Education

Name of Organization	Field Days	Demonstrations	Meetings Conferences Workshops	Publications	Farmer to Farmer	Media	Other
AERO			X	X	X	X	X
CA Certified Organic			X	X	X		
CA Clean Growers	X	X	X	X	X	X	X
CA Institute Rural Studies	X		X		X	X	
Center for Holistic Resource Mgmt	X		X	X	X	X	
Clagett Farm	X	X				X	
Committe for Sustainable Agriculture	X		X	X	X	X	
High Desert Research Farm	X	X	X				
Iowa Natural Heritage Foundation		X		X		X	
Kansas Rural Center	X	X	X	X	X		
Kerr Center	X	X	X	X			X
Land Stewardship Project	X	X	X	X	X	X	X
Maine Organic Farmers		X	X	X		X	
Meadowcreek Project		X	X		X		
Michael Fields Ag Institute	X	X	X	X	X		X

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Methods Used in Information Dissemination/Farmer Education

Name of Organization	**Field Days**	**Demonstrations**	**Meetings Conferences Workshops**	**Publications**	**Farmer to Farmer**	**Media**	**Other**
Nebraska Sustainable Agriculture Society		x		x	x		x
New Alchemy Institute	x	x	x	x	x	x	x
Northern Plains Sust. Ag.	x		x	x	x		
Ohio Ecological Food & Farm	x		x	x	x	x	
Oregon Tilth Inc		x	x	x	x	x	
Practical Farmers IA	x	x	x	x	x	x	
Rodale Institute	x	x	x	x	x	x	x
Rodale Institute-Arkansas	x		x	x	x		x
Seneca Trails RCD							
Sunny Valley	x		x	x		x	
Virginia Assn of Biological Farmers	x		x	x			
West Stanislaus RCD			x			x	
Winrock International			x	x	x		x
Wisconsin Rural Development Ctr	x	x	x	x	x	x	

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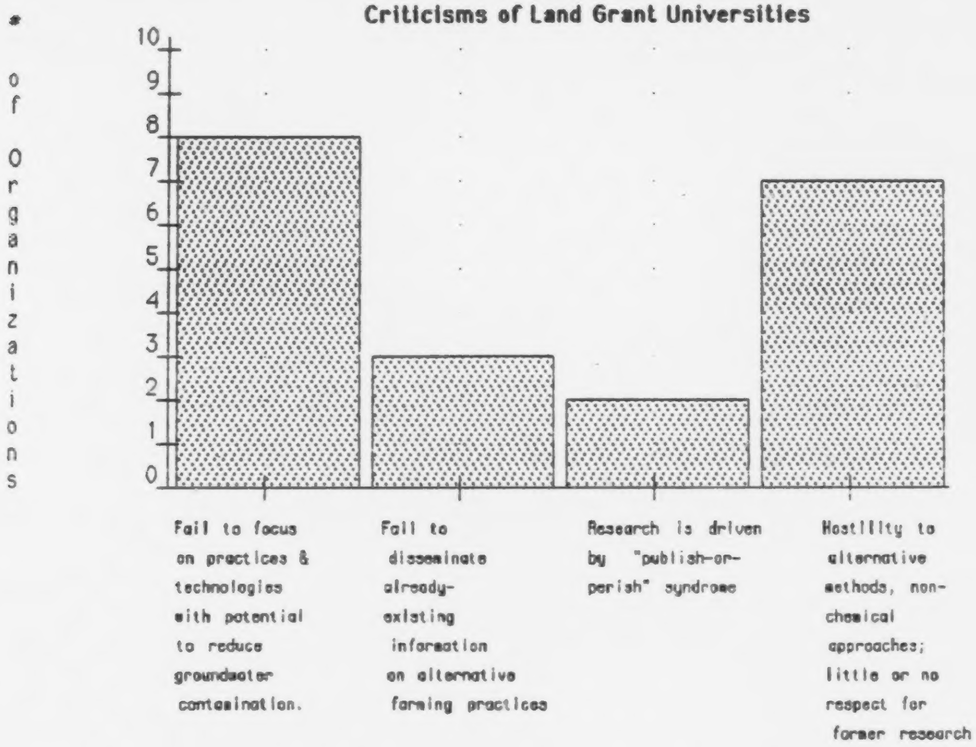
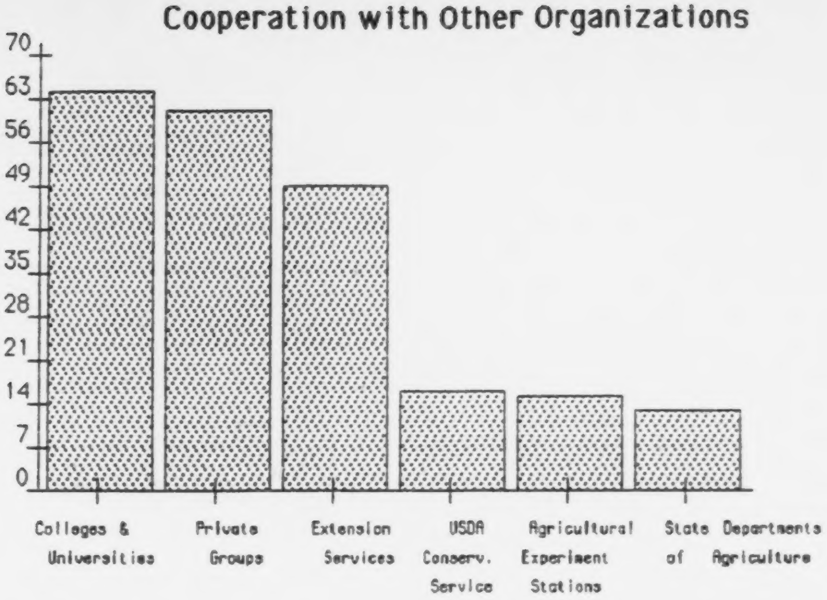
Criticism of Land Grant Universities

Respondents listed several criticisms of land grant universities, universities in general, and extension services. While the criticisms of all these institutions were similar, those directed toward land grant universities seemed more frequent and specific. They are summarized below.





This chart represents the number of cooperative research and education efforts reported by survey respondents with the most frequently reported types of cooperating institutions.

Land grant colleges predominate among the colleges and universities listed. Overall, as might be expected, colleges and universities are the most frequently reported cooperators. Respondents frequently report frustration with universities, particularly with land grant institutions, but still perceive them as extremely valuable partners in research and education efforts.

Private organizations are listed nearly as often as colleges and universities, with a wide variety of organizations listed as cooperating in research and education. Generally, these cooperative relationships are perceived as highly successful.

Other research relationships reported include:

USDA Agricultural Research Service	(10)
Soil and Water Conservation Districts	(9)
Chemical and Equipment Dealers	(6)
U.S. Forest Service	(2)
Other	(20 -- includes three reports of cooperation with the federal Environmental Protection Agency)

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Additional Organizations Cited by Respondents

Respondents were asked to name two or three additional organizations which, in their opinion, are making significant contributions to farming practices research and education related to groundwater protection. Respondents' names have been omitted, as a separate list is furnished with this report. But the organizations not surveyed which were commended for their good work are:

Acres, USA
Association of Applied Insect Ecologists
Bio-Integral Resource Center
California Action Network
California Sustainable Ag (Bill Leibhardt, Kerney field station)
Center for Holistic Resource Management
Center for Rural Affairs -- nominated by three respondents
Cornell University -- Department of Agronomy -- Dr. Robert Lucey
Grinnell 2000
Iowa Department of Natural Resources, Geological services
Iowa Natural History Survey (George Hallberg)
Land Institute -- "Wes Jackson's bunch"
Aldo Leopold Center at Iowa State University, Ames, IA
Mississippi Agricultural and Forestry Experiment Station
Nebraska Department of Agronomy and Ag Experiment Station
Necessary Trading Company
North Carolina State University -- Gar House, Larry King
Northeast Organic Farm Association
Ozark Organic Growers Association -- nominated by two respondents
Pennsylvania State University -- Dept of Agronomy -- Dr. Les Lanyon
Sierra Club
Southeast Wisconsin Farmer Research Network of Wisconsin
Steering Committee for Sustainable Agriculture (CA??)
Texas Department of Agriculture ("seems intent on supporting sustainable agriculture")
Valley Action Network
Washington Tilth
Wisconsin Department of Agricultural Trade & Consumer Protection
Wisconsin Rural Development Center

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INTEGRATING AGRICULTURAL AND ENVIRONMENTAL STUDIES IN COLLEGES OF AGRICULTURE AND NATURAL RESOURCES

by

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Rutgers University
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September 1989

This contractor document was prepared for the Office of Technology Assessment (OTA) assessment entitled Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. It is being made available because they contain useful information beyond that used in the OTA report. However, they are not endorsed by OTA, nor have they been reviewed by the Technology Assessment Board. References to them should cite the contractor, not OTA, as the author; a suggested citation format follows:

Author(s) name(s), Contract paper title, prepared for the U.S. Congress, Office of Technology Assessment, *Beneath the Bottom Line: Agricultural Approaches To Reduce Agrichemical Contamination of Groundwater* OTA-F-418 (Washington DC: U.S. Government Printing Office, November 1990).

ABSTRACT

In the 1960's and again in the late 1980's, citizen concern and intense media attention have focused upon human activities that threaten the quality of our environment. Political entities responded to this pressure in the 1960's and 70's by enacting legislation to establish the Environmental Protection Agency and to begin environmental education activities for the public at large and for specialists in areas with environmental impacts.

In the last two decades, environmental education/awareness programs were begun. Their continued growth is mostly in elementary and secondary schools, and in public and private environmental education centers. Environmental education of agricultural and natural resource specialists began to occur in the 1960's and 70's, and one can find environmental courses, "minor" and "major" programs in agriculture and natural resource (ANR) colleges today. The problem with the environmental education of agricultural and natural resource specialists is that there is not widespread adoption of these courses and programs. Few of the ANR colleges offer all three kinds of educational activities--courses, minor programs and major programs, and few require agriculture students to take environmental courses. Considerable curriculum renewal has been occurring in ANR colleges in the last few years, but thus far, environmental education is not being considered to any appreciable degree.

The inclusion of agricultural training within the programs for the education of college students in environmental sciences/studies (ES) is also spotty. Most of these programs exist in colleges with no agricultural faculty or course requirements in agriculture. Agricultural pollution or other negative effects of agriculture may be students' only contact with agriculture rather than a more complete understanding of managing the agricultural production and marketing system.

The Congress and federal agencies have the power to foster improvements in environmental and agricultural education. New legislation that created, for example, centers of excellence and a national grants program would give the issue the national coordination and visibility it needs and would lead to marked improvement in the education of agriculture and natural resource specialists in very short time.

INTRODUCTION

Public attention to agriculture's environmental impacts intensified with the publication of Rachel Carson's book, Silent Spring, in 1962. Examples of adverse environmental impacts from agricultural and forestry activities include soil erosion, deforestation, and pollution of groundwater and surface water. Some graduates of our nation's agricultural colleges will engage in activities that may have adverse side effects on the physical and natural environment (Davidson and Lloyd, 1977). This paper examines the current status of environmental studies in the United States agriculture and natural resources (ANR) colleges. The paper also explores options for colleges in providing opportunities for undergraduate students to increase environmental awareness, knowledge, and skills through environmental studies (ES). These studies consider problems caused by "human activity interacting with space, water, land and with other living organisms" (Institute for Environmental Studies, University of Wisconsin, Madison, 1984).

This paper focuses on undergraduate education programs in the land-grant universities and other public colleges with agriculture and natural resources education programs. These include three types of institutions: 1) 74 land grant (LG) colleges, established by 1862 and 1890 Acts of Congress, and eligible for membership in the Division of Agriculture of the National Association of State Universities and Land Grant Colleges (NASULGC); 2) 65 nonland-grant colleges, eligible for membership in the American Association of State Colleges of Agriculture and Renewable Resources (AASCARR), which is affiliated with the American Association of State Colleges and Universities (AASCU); and 3) 45 forestry schools, with curricula accredited by the Society of American Foresters. Programmatic responsibilities and organizational arrangements for ANR instruction vary considerably from college to college (see description, page 22).

Currently agricultural students in ANR colleges in the United States are educated primarily to address problems and concerns in agricultural science, production, and business. Their educational programs may not require coursework or experiences in environmental studies. About ten percent of the students enrolled in agricultural colleges major in natural resources--forestry, fisheries, wildlife, conservation, and related areas (FAEIS, 1988a, 1988b).

Environmental specialists, on the other hand, are concerned with environmental management and protection of natural resources. However, these specialists usually receive little or no training in forestry and agricultural practices. This situation may be partially explained by the fact that such scientists deal with environmental impacts from many human activities, not just forestry and agriculture. Also, many ES programs are offered in colleges or universities with no agriculture or natural resources programs (e.g., colleges of education, law, communication, and many liberal arts colleges). However, for environmental specialists located in areas with agricultural or forest-related businesses, it would help for them to have some knowledge of agriculture and forestry. The actual extent to which environmental specialists are trained in agriculture and forestry, however, is unknown.

A primary role of U.S. colleges and universities is to provide qualified people to maintain an economically viable food and fiber production system and to monitor the impact of human activity upon our environment--including agriculture (Coulter et al., 1986). How can ANR colleges in the United States offer educational programs that develop skills and sensitivities needed by graduates to address the impact of agricultural and natural resource practices on natural, social and physical environments?

One way for ANR colleges to respond to the concern about environmental problems is to include environmental studies in their programs.[1] Much environmental education--short courses, workshops, continuing professional education, minor, and major programs--may be found today in ANR colleges. The problem, however, is that there is not widespread use of this training by the ANR colleges, and few of their students are required to take the courses and educational programs. This paper examines current and potential means to integrate agricultural and environmental studies in undergraduate programs in ANR colleges.

This paper will address the undergraduate education of ANR students in the context of:

1) The present situation in historic perspective: A description and analysis of U.S. ANR higher education programs of study since the early 1800's to recent curriculum revitalization activities.

2) A future scenario; what an ANR college might be like in the future, based upon current trends; the use of a modified soft systems analytical approach as a basis for determining the mission and organization of an ANR college.

3) Constraints to change, suggested approaches, and policy implications.

HISTORIC PERSPECTIVE

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To understand the present condition and future prospects of ANR colleges, One must reflect on the early 19th century and examine why precursor colleges, i.e., the A & M (Agriculture and Mechanical Arts) colleges, were formed, the nature of American society, changes over time in American agriculture, and the evolving educational role of the colleges.

The higher education system of the 18th and 19th centuries was based upon the English college tradition and centered on the theological schools in America. The schools provided a "classical" system of education with course work in the classics, Latin, Greek, and philosophy. Although they also provided instruction in the natural sciences from an early date using lectures supplemented by the display of specimens and some demonstrations, few pursued more practical and focused instruction relating to agriculture and natural resources. However, around 1800, Timothy Dwight, a member of the New Haven County Agricultural Society, became president of Yale and sparked interest in relating the sciences to agriculture. Through the work of a series of proteges and the help of a benefactor, a professorship of agricultural chemistry and vegetable and animal physiology was established at Yale in 1842. It was filled by John Pitkin Norton, a well-educated person with farming experience who established a lecture series in agricultural chemistry and created a laboratory on campus.

By 1824, Rensselaer (Polytechnic) Institute in New York State, began offering agriculture-related instruction. Emphasis was placed on the practical application of science to daily life. Amos Eaton, Professor of Sciences at Rensselaer, used field exercises and observation in what was then a "novel" program. Many notable agriculturalists and naturalists emerged from this program. Other "agricultural and mechanical" programs were established in the early to mid 1800's at Amherst College, Trinity College, Harvard's Bussey Institute, and Farmer's College in Ohio. However, many of these were short-lived and phased out before or shortly after the Civil War (True, 1969).

Eighteenth and nineteenth century America was an agrarian society. In 1862, 48% of the U.S. population was engaged in agriculture (Aldrich, 1985). At that time, some of our country's leaders saw the need for a different kind of higher education institution to address practical concerns, resulting in the establishment of "people's colleges", or land-grant colleges, subsequent to the Morrill Act of 1862. Agricultural education in private colleges came to a virtual standstill shortly after the passage of the Morrill Act (True, 1969). The land-grant colleges formed slowly, taking many years before they were able to graduate students.

A review of the programs of study of the early land-grant institutions indicates that they focused on the application of science and technology to the practice of farming, i.e., the development of scientific farmers. However, since the 1860's, our society has changed from an agrarian society engaged in producing food and fiber to one in which less than 3% of the population performs those roles. The kinds of farm production units have also changed drastically, from a predominance of small family farms to a system dominated by large family farms and commercial "agribusiness" farms using advanced science and technology.

Scientific education for agriculture has been successful, and it remains a central mission of the ANR higher education system. However, as society and the nature of agricultural production have changed, so have we come to realize the importance of an education that prepares students to deal with the complexities of the systems in which agricultural production, consumption, and natural resource management take place. This education requires training not only in science and technology, but in economics of production, distribution, consumption, and resource management; the social, ethical, and political implications of governmental policies and regulations; and the historical and cultural bases of our own food, agriculture, and natural resource systems as well as of those of the rest of the world with which we interact (Merritt, 1985).

In 1982, the agricultural system provided employment for 21.5% of the work force in the United States and accounted for 20% of the gross national product (Aldrich, 1985). Agricultural sector personnel are employed in teaching (high school through graduate school), extension, farming and ranching, research, government service, and a broad array throughout business and industry.

CURRICULAR CHANGES: THE 1940'S TO THE EARLY 1980'S

The 1940's and 1950's: Undergraduate programs were primarily directed toward the technical, scientific, professional and vocational educational needs of students. A typical curriculum included extensive course work in biology, chemistry, the earth sciences, possibly math and physics, plus technical agricultural course work. Instruction in other disciplines tended to be both minimal and separate from the main thrust of educating agricultural students (Merritt, 1983).

1960's Through the Early 1970's: This period, especially the 1960's, was an era of rapid expansion in higher education facilities, faculties, programs and student numbers. The public in general placed a high value on higher education and there were large numbers of college-age individuals. Governments, colleges and universities responded to the needs of large numbers

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of young persons who wished to attain higher education. The public was willing to support more higher education, and there was good support from business and industry (Merritt, 1983). In the environmental studies area, many of our colleges responded with new programs, new courses, and research (Aldrich and Kormandy, 1972).

In agriculture, ANR colleges increased their programs, student body and faculty size and explored many innovations in teaching and curricula. Activities of three groups contributed to many of the curriculum changes in agriculture and natural resources: 1) the National Academy of Sciences' Commission on Education in Agriculture and Natural Resources (CEANR), whose mission was to stimulate improvement in the undergraduate education of future agricultural scientists and professionals (Geyer, 1965a, 1966); 2) to a lesser extent, the National Academy of Sciences' Commission on Undergraduate Education in the Biological Sciences (CUEBS), which had a similar role for the biological sciences (Geyer, 1965b); and 3) the Kellogg and Knapp study of agricultural colleges supported by the Carnegie Foundation, which produced an "idea" book challenging agricultural colleges to consider changes in their missions (Kellogg and Knapp, 1966).

Among the resultant changes in undergraduate programs were:

1) New curricula and courses in agricultural business and marketing.

2) The addition of new introductory agricultural courses such as "plant sciences", "animal sciences", and "man and his food", designed to serve majors and non-majors in both agriculture and liberal arts curricula.

3) More course work in literacy, including the addition and enhancement of courses in technical and scientific writing, speech, and communications.

4) The introduction of course work and programs in Integrated Pest Management (e.g., at Texas A & M University, University of California--Davis and Berkeley, North Carolina State University).

5) In a few institutions, such as the University of Wisconsin, Rutgers University, and University of California--Davis, new courses and programs in environmental science and environmental studies.

6) Again, in a few institutions, re-design of courses and the creation of new courses to bring in systems theory and analysis and ecology. This effort was accompanied by the development of some inter- and multi-disciplinary[2] courses and multidisciplinary curricula, because some faculties were concerned that progress in agriculture in the United States required graduates who had not only scientific and technical competence, but also competence to deal with related public policy, social and cultural issues. The few institutions able to do some of this were the University of Wisconsin, University of California--Davis, and Rutgers University.

7) A few courses considering humanistic perspectives on agriculture and technology, principally ethics.

8) Some new courses and curricula in international agricultural development.

9) Work study, cooperative education and internship programs to help students apply classroom knowledge to the real world.

Significant curriculum renewal occurred in the 1960's and early 1970's compared to the pre-1960 period. Many innovative and highly desirable improvements were begun. However, few were given adequate support to develop and diffuse to other institutions. The era now seems one of unfulfilled potential.

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The Late 1970's and Early 1980's: Recession, inflation, reduced enrollments, and lowered public support for higher education reduced the real value budgets for U.S. colleges and universities. The period was one of retrenchment" (Merritt, 1983, 1985). Notable exceptions to retrenchment included the further development of programs and courses in agricultural business, with industry support (Merritt, 1983). Also, the 1977 Farm Act authorized the transfer, from the Department of Education to the Department of Agriculture (USDA), the responsibility for higher education programs in agriculture. This led to the establishment of the USDA Office of Higher Education Programs.

Another exception has been the continued environmental education of U.S. citizens, which began in the 1960s. Much of this education was aimed at raising citizen awareness of the value of the environment and the importance of protecting it. Environmental education has been accomplished primarily through: 1) elementary and secondary school programs taught by teachers who elected environmental awareness courses or enrolled in the over 200 graduate programs in environmental education; 2) public education programs in the more than 3000 environmental education centers in the U.S.; and 3) public education programs by the U.S. Forest Service, the National Park Service, Garden Clubs and other private environmental groups (Kirk, 1982, 1988; Lewis, 1988). These efforts plus the emergence of the professional area of environmental communications as a major activity may well be the impetus for so much public concern about environmental risks (Kirk 1988; Schoenfeld, 1982; Lewis, 1988).

CURRENT ANR COLLEGE PROGRAMS

In 1987, ANR colleges enrolled a total of 77,734 baccalaureate students in agriculture and natural resources (FAEIS, 1988a, 1988b). The 74 land grant colleges enrolled about 57,000 baccalaureate degree students in agriculture and related areas. The 65 colleges of the American Association of State Colleges of Agriculture and Renewable Resources (AASCARR) enrolled approximately 21,000 students. The 45 schools of forestry with accredited curricula matriculated 10,209 undergraduates. Nineteen of the forestry programs are offered by nonland-grant and AASCARR institutions. To put the numbers of agriculture and natural resources undergraduates in perspective in 1988, the U.S. had an undergraduate enrollment of 7.8 million students and the high schools were expected to graduate 2.7 million students (The Chronicle of Higher Education, September, 1988).

Table 2 identifies the major groupings of degree programs offered in agriculture and natural resources and gives 1987 enrollment statistics in the LG colleges by all degree levels (FAEIS, 1988a). ANR programs of the AASCARR colleges are similar to those in Table 2. The diversity of specializations within these programs is very extensive and totals 75. Analysis of these data for the baccalaureate level are 1) highest enrollments are in animal science (20%) and agricultural business (14%); 2) environmental science majors listed as natural resources majors constitute 10% of the enrollment. Since some ES majors which are not natural resources majors are listed in "other programs," the total percentage of ES majors may be slightly higher; 3) no less than 64% of the total are in applied or basic biological science programs; 4) social sciences, business, communications and education constitute 19% of the total. Thus, the ANR colleges are principally science and technology institutions.

An examination of course catalogs of ANR institutions indicates that curricula are multidisciplinary with a broad liberal education component, a science component, and depth in a major area. None of the ANR colleges requires agricultural science students to take ES courses, with the exception

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of Rutgers University. ANR colleges generally offer ES courses as electives. There are also no interdisciplinary curricula in the ANR system. There are, however, many interdisciplinary courses offered at some of the colleges which are listed in Table 3.

Environmental Studies Programs. The 1960's and 1970's was an era when environmental studies professional programs began. EPA supported research in the universities in the health sciences, biology, physics, chemistry, and engineering. The Department of Health, Education, and Welfare, under the aegis of the 1971 Environmental Education Act, supported teacher education programs and other educational activities (Lewis, 1988). The national mood at that time was to have both citizen and specialists receive environmental education. Professional environmental studies curricula were begun in many different kinds of colleges in addition to the ANR colleges. The response of the higher education community in the 60's and 70's to environmental concerns was to offer three levels of environmental education activities: a) environmental awareness courses or course modules appropriate for all students in any curriculum offered in a college, b) environmental studies "minor" or certificate programs which may be elected by students, and c) professional career programs.

Environmental Awareness Courses. Environmental awareness courses delineate the environmental issues and what is being done in both public and private sectors to create, ameliorate and prevent environmental problems. A list of representative courses is given in Table 3.

Some of these courses represent an integration of both agriculture and environmental studies and are interdisciplinary in nature (Catalog, University of California, Davis, 1988-89; Bulletin, Institute for Environmental Studies, University of Wisconsin, Madison, 1984; Catalog, Rutgers University, 1987-89).

Environmental Studies "Minor" Programs. Environmental minor programs are offered by the University of Wisconsin and Rutgers University. These take different forms and may give the student some understanding of environmental issues, the interaction between science and our society, and some skills. One such program, described in Appendix 1, consists of a certificate program of 24 semester credits entitled "Social Strategies for Environmental Protection" offered by Cook College, (Catalog, Rutgers University, 1987-89).

Environmental Science/Studies Professional Programs. Environmental professional programs provide all levels of degrees--from Associate degrees for environmental technicians through Ph.D. programs. Careers related to the environment are many and varied. The objective of these programs is employment in governmental agencies at the local, regional, state or federal levels, in school systems, environmental groups, or in the private business sector. Table 4 gives a list, by no means all-inclusive, of environmental baccalaureate programs found in some ANR colleges (University of California, Davis, Rutgers University; Clepper, 1979; Fanning, 1981; Merritt, 1971, 1974, FAEIS, 1988a; 1988b).

The environmental studies and science courses, minor programs and career programs described above are found in ANR colleges, but few offer the number and breadth described in the preceding section. Also, the inclusion of agricultural studies in environmental programs is very limited, since so few ANR colleges offer the professional Environmental Science/Studies career programs described above. Several publications describe other environmental programs and careers (Taylor, 1980; U.S.E.P.A., 1980).

Agricultural Teacher Education Programs. Agricultural teacher education programs are either offered by colleges of education or are jointly offered by ANR and education colleges. Its graduates are the teachers of vocational

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agriculture programs at the secondary educational level throughout the U.S. Environmental education is normally not a structured part of these programs anymore than would be the case for the other agricultural majors. Prospective teachers may take environmental awareness courses, or minor programs, and in some cases, portions of courses which consider environmental issues. They may also enroll in a graduate master's degree level program in environmental education.

Continuing Professional Education Programs. On-the-job training or enrollment in unit short courses is yet another way to obtain environmental science skills/ sensitivities. Some colleges offer extensive unit short courses in environmental areas appropriate for those working as environmental professionals, or for students enrolled in ANR and ES baccalaureate programs. Table 5 is a list of environmental studies programs (short courses and continuing professional education) offered by one ANR college.

ROLES OF AGENCIES AND INSTITUTIONS

Responsibilities of several federal agencies are related to integrating agriculture and environment in higher education.

USDA. In 1977 Public Law 95-113 designated the USDA as the lead agency for higher education in food and agricultural sciences. Subsequently, the USDA established the Office of Higher Education Programs. Personnel in this office working with the national higher education associations have attempted, with limited funding, to provide leadership to address national priority higher education needs established by the Joint Council on Food and Agricultural Sciences and its subordinate units. Considerable progress has been achieved in establishing a national food and agriculture education data base system (FAEIS, or Food and Agriculture Education Information System) at Texas A & M University for programs, enrollments, faculty characteristics, and manpower projections, among others.

Other major thrusts have focused upon curriculum revitalization, faculty development, agribusiness management and marketing education, and student recruitment/retention, particularly through graduate fellowships. To date, agriculture and environment integration in higher education, over and above what is presently in effect in US colleges, has not surfaced on the national action agenda.

US Agency for International Development (USAID). The Federal agency USAID has been involved in bi- and multilateral projects related to agricultural higher education since the end of World War II. Most recently, USAID completed a three year study of agricultural universities and faculties in the developing world which have received U.S. funding. The objective of the study was to assess the impact of the agricultural colleges on rural development in the Third World countries and to identify issues which must be addressed to assure that they will adapt and respond to societal changes in the twenty-first century (Hansen, 1988). Members of the National Agriculture and Natural Resources Curriculum Project (NANRCP) participated in these reviews. NANRCP "Systems" materials developed primary for US universities have become a key analytical tool in the three year study and are forming the basis for college and university mission reevaluation in the developing countries. USAID sponsored a major international systems conference in October 1988 (see addendum 2). Other USAID activities are currently in the planning stage. The issue of agriculture and environment integration in higher education is not an identified high priority, but logically it should become one.

U.S. Environmental Protection Agency. The Environmental Protection Agency (EPA) is the agency responsible for the Federal laws to protect the environment. In 1970, when EPA was established by Executive Order, as a result of the 1969 National Environmental Policy Act, existing programs from several different agencies were combined into this new, single agency. Fifteen components from five Federal departments were transferred to EPA. Since that time, Congress has continued to enact both major new laws and important amendments to older laws which have changed and greatly expanded EPA's role.

The focal points for environmental education at EPA are currently found in two primary offices. The Office of Community Relations, housed in the External Affairs' Office of Community and Intergovernmental Relations, has primary agency responsibility for environmental education from grades K-12. This office coordinates the activities of a Headquarters staff and 10 Regional Youth Coordinators, who organize and sponsor meetings, seminars, and conferences (Lewis, 1988). At the postsecondary level, EPA's Office of Cooperative Environmental Management operates a National Network for Environmental Management Systems and oversees the National Advisory Council for Environmental Technology Transfer. Federal funding to state agencies provides the financial base for the unit short courses and continuing professional education programs. In summer 1989, proposed legislation (the National Environmental Education Act) was introduced in the Senate, calling for the creation of an "Office of Environmental Education" at EPA, and would reorganize the agency's efforts (K-College), and establish EPA as the coordinating Federal agency for environmental education. Also in the summer of 1989, the EPA Administrator appointed a Special Assistant with the specific responsibility of tracking environmental education initiatives.

U.S. Forest Service and the National Park Service. These agencies continue to offer or sponsor environmental education workshops and short courses. The impetus for these came from the Environmental Education Act, which in 1981 was subsumed by the Education Consolidation Improvement Act.

ANR CURRICULUM RENEWAL EFFORTS, 1981-89

National Agriculture and Natural Resources Curriculum Project (NANRCP). In 1981, the National Higher Education Committee of the Joint Council on Food and Agricultural Sciences of the USDA established a national agenda for colleges of agriculture and natural resources. The highest priority item on their agenda was the need to assist colleges to revitalize their curricular programs. This led to the establishment of the NANRCP, initiated in 1982 with USDA funding, and subsequently supported as well by 26 business and industry firms, and colleges and universities. The NANRCP was directed by a task force from the Resident Instruction Committee on Organization and Policy (RICOP) of NASULGC, AASCARR, the National Association of Professional Forestry Schools and Colleges (NAPSFC), the USDA, and business and industry representatives. The first activity of the project was to assess what were unmet curriculum needs. The first year surveys and regional and national meetings were held to determine the list of curriculum areas of areas of high priority not adequately represented in ANR curricula. These were determined to be:

1. Computers in Agriculture
2. Systems Approaches to Food, Agriculture and Natural Resource Problems
3. Ethical Aspects of Food, Agriculture and Natural Resource Policy
4. Problem Solving
5. Cultural and Social Aspects of Domestic and International Agricultural Systems
6. Energy Use in Food and Agricultural Systems
7. Integrated Reproduction Management
8. Man and His Food - Biological and Consumer Aspects
9. Systems of Integrated Pest Management

10. Leadership Development
11. Internships and Cooperative Education
12. Student Projects

An action plan and a process for addressing needs were established. Two national and international teams of faculty and business persons worked for 3 years each to develop course and curriculum materials for the 2 highest priority areas other than computer use, which most colleges had begun to address: 1) Systems Approaches to Food, Agriculture and Natural Resources; and 2) Ethical Aspects of Food, Agriculture and Natural Resource Policies.

Concepts and techniques for reviewing and revising curricular programs were developed. Course and curriculum materials have been disseminated by 1) eleven training workshops/symposia on "Systems" which have been presented to over 500 faculty, administrators and others representing about 40% of the land grant and AASCARR colleges in the U.S. and a substantial number from other countries; and 2) two "Ethics/Policy" Training Workshops which have been presented to 60 faculty and administrators from 40 colleges, government and business organizations.

Two books on "Systems" and one on "Ethics and Policy" will be published in 1990. Professional societies (Agronomy, Agricultural Economics, and Horticulture) have also published articles on the National Curriculum Project. Two societies (Agronomy and Agricultural Economics) have held symposia on "Systems", and an "Ethics" symposium has been held by the Agricultural Economics association. (See also Appendix 2).

Many faculty in ANR colleges are considering the approaches and materials produced by the NANRCP and others, and some colleges are modifying their curricula. Changing student clientele (i.e., more women students, older students, students with no farm experience) and reduced enrollments appear to be the major motivating factors for curriculum change. Extensive changes have recently been approved at the University of Minnesota. Others actively involved in ANR curricular revitalization activities are the University of Wisconsin, Michigan State University, California State Polytechnic University, Pomona, University of Nebraska, University of Hawaii, and Washington State University among others. Many other ANR colleges have included systems and ethics courses or course modules within their programs. Some colleges have made joint appointments for philosophers to teach agricultural or environmental ethics courses - University of Florida, Texas A & M University, Washington State University. Minor to major curriculum revitalization efforts are occurring in the ANR colleges, but few have begun to consider expansion of courses and programs in the environmental studies areas. This is probably due to the many constraints to curriculum renewal discussed below. The issue of including ES in ANR curricula has recently been discussed as part of the new national ANR curriculum effort, Project Interact, which is described in the next section.

OTHER NATIONAL CURRICULUM RENEWAL ACTIVITIES

Project Interact. Project Interact is an integrated curriculum development project supported by a grant from the Office of Higher Education Programs in USDA's Cooperative State Research Service. Its purpose is to continue national curriculum revitalization efforts begun in 1981 to assist ANR faculties to respond to their clienteles' changing needs with high quality programs. The first meeting of the executive committee was held in March 1989, and the following national projects were reviewed (Kunkel, 1989):

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Problem Assessment of Forestry Education Project. The forestry colleges have recently completed the first phase of an assessment of their programs and program needs in response to a 40 percent decline in enrollment from 1978 to 1986. An assessment report is being prepared.

Agribusiness Education Development Project. This project is focused at the graduate level in partnership with Colleges of Business. It has concentrated on 1) M.Sc. level education in business and technical agriculture, 2) executive development through continuing professional education, and 3) faculty development programs.

Curriculum Innovation for 2005 Project. This project of the north central region ANR colleges had as its purposes: 1) the identification of concepts and philosophic issues; 2) a review of curriculum literature; 3) the evaluation of current curricula offerings; and 4) the development of future curricular models. The project produced a series of essays and a national symposium from which a proceedings document was prepared (Sledge, 1987). This regional study presented issues and approaches for faculties to consider in their efforts to revitalize curricula.

National Agriculture and Natural Resources Curriculum Project. The NANRCP project is described in the previous section.

Project Interact has also formed three task forces to discuss curriculum renewal in three areas: 1) guiding principles for marketing, development, delivery systems, flexibility, purposes of agriculture and kindred colleges; 2) colleges of agriculture in the future; and 3) curricular design. The third task force included environmental issues in its report. Project Interact, an outgrowth of the NANRCP, may well provide a mechanism for more emphasis in environmental studies in ANR curricula.

Over the last five years, several talks and papers have been written concerning the need to revitalize ANR curricula. The article entitled "Land-Grant Undergraduate AG Programs: They Need Revitalizing" (Connor, 1989) cites reasons for change and some possible changes, but ES sensitivities and skills are not mentioned except as natural resource general education. Shuh's 1986 article, "Revitalizing Land-Grant Universities, It's Time to Regain Relevance" states, "The basic challenge of today's Land Grant University is to bridge the gap between society's current problems and the frontiers of knowledge." Hoshmand, in a 1988 National Association of Colleges and Teachers of Agriculture (NACTA) Journal article, describes the use of NANRCP materials in "Systems Teaching--A Direction for Faculty Development and Curriculum Revitalization." Kirkendall (1987) indicates that the quality of the agricultural system depends significantly upon the quality of its intellectual life--its science, "including its social science, which has the capacity to sort out myth and reality in agriculture in agriculture and explore, develop and evaluate ways of making the system function more effectively". He and Johnson (1989) point to a significant role for the humanities in such an effort. Hushak (1989) suggested potential new directions for agricultural colleges including several with environmental emphases, such as sustainable agriculture, groundwater and surface water quality, and pesticides and toxic substances in the environment. Bawden et al. (1976) stressed the need to include systems thinking and practice into the curriculum.

Another aspect of the NANRCP was to prioritize the areas which needed to be revitalized in ANR curricula. Except for Integrated Pest Management, no environmental science or studies area emerged as an area of concern for ANR administrators or their faculty committees. The ANR colleges have programs concerned primarily with science, technology, engineering, education, and business. Within these programs, some modification is occurring following recent trends and the production of course materials, software and hardware, including computer literacy, ethics and agriculture, systems approaches to inquiry into complex situations, molecular biology and biotechnology. The other major components of the ANR Curriculum are unfortunately represented as "service" areas rather than integral and possibly equally important parts of the curriculum (Merritt, 1985). These would include environmental studies, communications, social, cultural and political aspects. Few ANR colleges include them as meaningful equals. All of these areas must be considered in the education of future ANR graduates in a meaningful and integrated fashion (Sledge,1988).

CONSTRAINTS TO ANR CURRICULUM RENEWAL EFFORTS

ANR curriculum renewal has been enhanced by a national focus on the problem by the USDA and the key ANR national college and university associations (NASULGC Division of Agriculture, AASCARR, and the NAPFSC) Accomplishments have been described in the previous sections. There have, however, been more constraints to development in the past decade than support for change. The primary constraining factors are:

1) U.S. governmental policies which state or imply that all education, including higher education, are the responsibility of the states rather than a federal responsibility. With few exceptions, such as some fellowship programs and the $300,000 available this year for national higher education efforts in the USDA Higher Education Office, there is virtually no support available for national ANR higher education efforts. While most higher education efforts should be a state responsibility, there are many major issues confronting U.S. ANR higher education that require a national focus and funding.

These issues include: 1) environmental effects of current and new technological advances in U.S. agriculture and industry, such as ground and surface water contamination by fertilizers and pesticides and their effects on people, animals, and plants; water as an increasingly limited resource for human, industrial and agricultural purposes continues to be polluted by activities of all kinds; air pollution effects on people and crop production; and acid rain effects on trees; 2) the safety, quality, and quantity of our food and fiber supply for domestic and export purposes; 3) energy conservation, formation, and utilization; and 4) the increasing concern about the U.S. higher education system (Bennett, 1984; Connor, 1989; Mortimer, 1988). Transmitting new knowledge to ANR faculty and students and our citizens is very difficult to do at the level of the individual university, because the academic reward system tends to place a higher priority on research than on teaching and curricular reform. A positive step towards curriculum renewal in U.S. ANR colleges would be Federal activities with high visibility providing the impetus and partial rewards for college faculty involvement. The major national associations (NASULGC, NAPFSC, AASCARR) and the disciplinary associations could assist these efforts by 1) including environmental issues as one of their high priorities; 2) developing position papers; and 3) sponsoring symposia.

2) Support from businesses and foundations is usually focused at a geographic area of business interest, an individual, an institution, a state, or at the regional level. Twenty six businesses and foundations did support the NANRC project. These were among the few who would consider funding a national project.

3) College and university reward systems, such as salary and promotion. Many institutions reward those who have excelled in research scholarship. Scholarly efforts aimed at course and curriculum renewal seldom are rewarded, especially at the larger research universities (Johnston and Brandenburg, 1987; Kunkel, 1989).

4) Faculty interest and desire to implement change. Many faculty, particularly those in the land grant system, have the majority of their salary support for research, rather than teaching. Encouragement by the college and university administration and the concomitant reward for program renewal efforts must be in place. Development of new inter- and multidisciplinary courses and other learning activities takes considerable time and personal sacrifice. There are few national networks for ANR disciplinary or multi-disciplinary teaching. Individual efforts which include the development of course and curriculum materials takes considerable time and effort probably equal to that of doing research. Since few faculty will receive any reward for doing this, it becomes difficult to achieve. A national team effort as has been done with the NANRCP is attainable and can provide the teaching/learning tools required. Faculty training sessions also are needed if a substantial national change is to occur. One would assume that professionals in higher education would have continued professional development and education. While it usually occurs through research and professional societies, little is done in the continuing professional education of those who teach in colleges and universities. Other professions in our society are better structured to include continuing professional education in their activities than is higher education (e.g., medicine, veterinary medicine, and the allied health profession areas).

5) Bureaucratic and institutional constraints. Most ANR colleges exist within complex, large universities which may have twenty or more colleges. If University policies foster management at the college level, change may occur more easily in an ANR college than one which has many university-wide curricula and course requirements, approval mechanisms, etc. ANR colleges are parts of larger organizations and must respond to the dictates of the larger organization. Other professional colleges such as medicine, veterinary medicine, and law, etc., may have more autonomy within large universities than do ANR colleges which do not in most cases consider themselves to be professional colleges (Merritt, 1983).

Professional college curricula are usually influenced by national professional societies and sometimes legislation, and the colleges are accredited by professional associations. ANR colleges may have a few professional departments that operate in a fashion similar to the professional colleges (e.g., agricultural engineering, agricultural education, forestry, landscape architecture, meteorology). However, most ANR faculty departments are organized as applied biology units, plus one or more units in economics or social science or other areas. These departments and their curricula are not subject to professional accreditation.

In professional colleges, professional faculties may offer 65% or more of the total course credits in the college curricula. In ANR colleges, on the other hand, ANR faculty often offer only 30-40% of course credits, while faculties in the associated liberal arts and sciences colleges (with strong agendas of their own) offer the largest part of the typical ANR curriculum.

Also, ANR colleges exist in many different organizational forms. These may be 1) an agricultural college (AG) focused upon the food and fiber system--its science, technology, and business; 2) AG plus home economics; 3)

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AG plus some or all of the biological sciences; 4) AG plus natural resources, areas of forestry, wildlife, fisheries, park management, etc.; 5) AG plus environmental studies in water, air, health, radiation; 6) AG plus the social sciences--sociology, psychology, anthropology, history, political science, geography; 7) AG plus ethics; and 8) any combination of the above plus others.

Land grant ANR colleges have research, extension, and teaching budgets and functions. Teaching is usually the smallest part and frequently receives the least attention. The implications are that ANR faculty and administrators have a wide array of agenda items and the smallest budget and functional area is considered last. The many different kinds of curricula offered, each with a different focus, gives rise to extremely complicated situations. Then add the fact that most of the curriculum is offered by other faculties. All of this results in many compromises, change being difficult and time-consuming to achieve. A professional faculty, in contrast, that controls most of the curriculum can achieve changes in the curriculum more readily than many, if not most, ANR colleges.

Another constraint is that faculty are organized into single discipline departments that control the curriculum. Such an arrangement often makes it difficult to develop interdisciplinary programs.

6) Little funding available. In general, little funding is available for program modification activities within the college or the university.

7) Low response from professional societies. Several professional societies, especially the agronomists and the agricultural economists, have begun to address curriculum reform. Higher education reform will move more quickly when more of the professional societies concern themselves with the education of our students as well as new knowledge developed. In general, however, most professional societies largely ignore higher education issues.

COMPETENCIES

What then might be the environmental skills, sensitivities and competencies that our ANR graduates must have, and what agricultural sensitivities must environmental scientists have?

The following is a minimum list of potential goals for use in designing courses, course modules, or curricula whose aim is to integrate agriculture and environment in higher education. Learning experiences should be available to develop:

1) Knowledge, appreciation and understanding of the human activity system in which we live and the impacts of human activity on the quality of the environment.

2) Knowledge and understanding of the methods which may be used to identify, analyze and solve problems or improve complex human/environment situations, e.g., computer simulations.

3) Knowledge and understanding of ethical decision making and the importance of ethical considerations when addressing human activities and their impact on the environment.

4) Skills to communicate orally and in writing; to translate theory into practice; and to perform quantitative functions.

5) Technical, social, humanistic, and/or business skills.

6) Understanding of government policies and regulations and effective means of implementation.

The best way to gain environmental sensitivities is through courses and learning experiences in which students get involved in the process--to do field work or use other experiential learning modes. The lecture method is the least effective way to involve students in learning about the environment.

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STRATEGIES FOR INTEGRATING ES AND AGRICULTURE

Enrollment in ANR colleges in recent years has declined substantially (Hess, 1989; Thompson and Massey, 1989). Few if any ES curricula were established in ANR colleges. It has not been an era of high public concern or support for US higher education. It has in fact been an era marked by considerable criticism of the higher education community and its programs (Bennett, 1984; Curtis, 1985; Eurich, 1985; Lewis, 1988; Mortimer, 1984). Funding for program revitalization has been a scarce commodity for most ANR colleges. Only a few ANR colleges have been given funds from foundations to engage in significant curriculum modification activities, e.g., Universities of Minnesota, Nebraska, and Wisconsin.

Environmental concerns are greater today than in the 1960's, but the response of higher education appears to be much less than the 1960's and 1970's. Some of the reasons described above may be major contributing factors. Now might be an opportune time for the Congress and the Executive Branch of government to finance a new comprehensive environmental science/studies education effort to highlight the national concern and lead the way towards the further education of our professionals in ANR and ES. There is already much in the higher education system upon which to build.

Below are three options for focusing limited federal funds into programs which could have a substantial effect on our ANR colleges and their graduates.

OPTION 1: USING SYSTEMS APPROACHES FOR CURRICULUM CHANGE

What follows is a very brief overview of a process used successfully to review and revise courses, modules, curricula and other related learning activities. This process, a "soft systems approach," can be used as an analytical tool to determine the kinds and content of environmental or agricultural studies in a curriculum (Merritt and Wilson, 1989). Soft systems approaches conform to models of experiential learning. This model describes learning as a cycle of activities in which people initially explore experience, reflect on its probable meanings, assimilate it into conceptual frameworks in order to create knowledge, actively apply it in planning, problem solving, and decision-making, and act to create new situations. It differs from other inquiry approaches by being learning-based and participatory (Wilson and Morren, 1990).

The process is based on asking key questions and uses systems techniques (Figure 1). The key questions are the "what," "why," and "who" questions, such as "What are the objectives of the program? Why was it established? What sector of society does it serve? What guidelines, laws, regulations affect the program? What skills and competencies must its graduates have? Who has the power to approve changes? Who are the main groups concerned with the program? What constraints to change exist, etc.?

Systems approaches and techniques are ways of thinking about and analyzing a total system and its component parts as opposed to analyzing only a single component. Human beings address holistic situations (total systems) in their daily lives. Systems approaches are attempts to study reality. Hard systems inquiry usually attempts to mathematically describe reality and uses computer models. It is an invaluable aid to decision-making, but encounters problems when human behavior must be quantified. Soft systems inquiry is valuable when there are complex situations with considerable human interaction. It is an appropriate method to use with complex human activity systems. It is an interactive method between analyst and the main groups concerned and often uses hard systems techniques as described in Figure 1.

The process includes information gathering (key questions), assimilation of information, creative interaction with main groups on possible improved future programs, identifying the main changes that would have to occur for improvement, modeling improved situations, feedback from main groups, and then a plan(s) for an improved program.

The soft systems approach would be an excellent exercise in planning for changes in future ANR college programs. Detailed approaches are described in the forthcoming book, "Systems Approaches for Improvement in Agriculture and Resource Management" (Wilson and Morren, 1990). If the ANR colleges were fully contained professional colleges or if states were to begin an ANR college de novo, the mission and the organization would be easier to forecast if human and fiscal resources were available. What we must look at are the change(s) in highly bureaucratic organizations, and if they desire change it will be done in a slow, deliberate manner. It is clear, however, that many of these institutions want to change, and change at some level is occurring -- in courses, curricula, and in some cases the organization of faculty units.

ANR colleges for the future may well be colleges with faculty from the life, physical, social sciences and humanities rather than as most of today's colleges which are life science colleges with some chemistry, economics, teacher education and possibly rural sociology. The ANR college of the future based on recent trends and criticisms might well include faculty departments, or subunits and programs in communications, computer science, geography, history, ethics, anthropology, sociology, political science, planning, law, business and economics, in addition to the traditional areas. These areas are now key components of the world food system today, and will probably be represented as equal partners in tomorrow's ANR college.

OPTION 2: CENTERS OF EXCELLENCE PROGRAM. The federal government has had similar programs in the National Science Foundation (NSF) and the National Institutes of Health (NIH). The goal of the program would be to direct five to ten year funding for two to four regional ANR colleges to develop strength and experience in all three levels of ES as described previously. These colleges would have to provide the positive environment, reward system, and flexibility to respond quickly to implement a national or regional ES/ANR dissemination and development program. Annual program performance goals would form the basis for continued funding. Activities might include faculty and administrator workshops, consultant services, major conferences, course and curriculum materials development, evaluations of progress, publications dissemination, the use of television, and computers. The contracting universities should also commit a certain percentage of their funds into the effort and, as in the past with NSF Centers of Excellence Grants, agree to institutionalize a major portion of the program after ten years.

OPTION 3: NATIONAL GRANTS PROGRAM. A focused national grant program whose goal would be to institutionalize within all or many ANR and ES programs course units (modules) or courses, or other learning experiences in either ANR or ES along with faculty development activities. The long term commitment of the universities to support the continued learning activity on a "hard money" basis would be essential. Too many grant funded activities support "soft money" ad hoc educational activities which disappear when grant funding ceases.

The inclusion of a grants program as part of a Centers of Excellence program might well be the quickest way to impact the ANR and ES education system.

CONCLUSION

Our nation's ANR programs should include learning experiences to improve the environmental skills and sensitivities of professionals. However, national will, leadership and action programs are required. The concomitant issue, not the focus of this paper, concerns environmental education of all our citizens. This should continue to be addressed and its programs enhanced (Lewis, 1988). Integrating ES to a greater extent into our nation's ANR colleges can be difficult, because these institutions are complicated organizations. The national goal should be to improve the situation considerably and will require state and local support.

FOOTNOTES

[1] The responsibility for creating, evaluating, and revising curricula and courses varies from institution to institution. In general, the departmental faculty offering the program has the primary responsibility for originating, offering, evaluating, and revising courses and curricula. In addition, college or university committees, the university senate, and academic administrators often have review and/or approval roles. Creating a new curriculum is the most complex activity and additional approval is often required by the institution's governing board, possibly State government higher education agencies, and in some instances, the State legislature. Curriculum evaluation, in addition to that done by the faculty, is performed on a regular basis by regional higher education associations, and if it is a professional program, by its professional accrediting unit.

[2] Multidisciplinary instruction means that specialists from two or more discipline fields contribute discipline units of instruction, but not in an integrated fashion. Interdisciplinary instruction means that discipline specialists work together to integrate their discipline knowledge to form a cohesively integrated instructional package.

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FIG. 1 SOFT SYSTEMS INQUIRY PROCESS AND LEARNING
Adapted from Wilson and Morren 1989

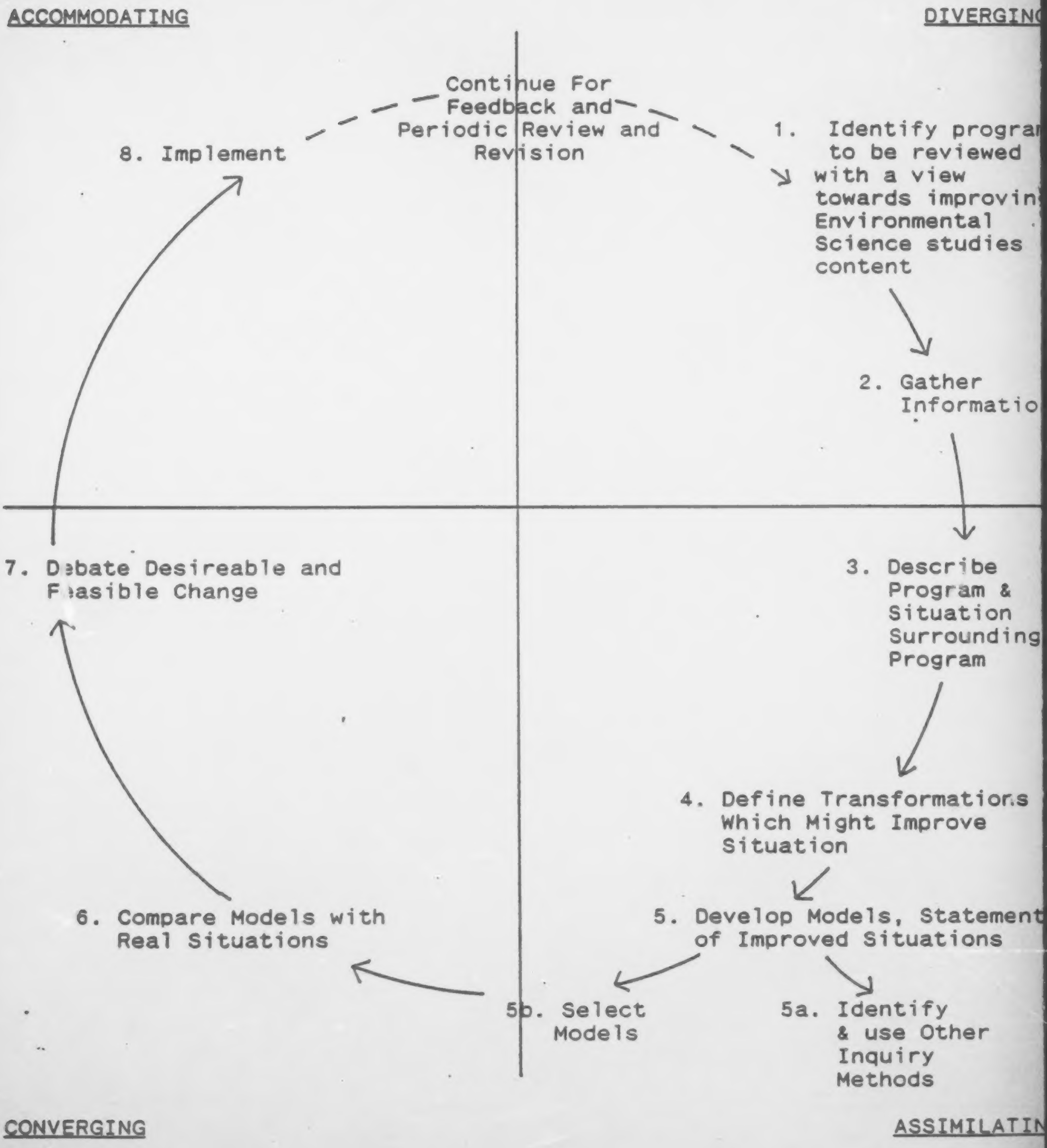
ACCOMMODATING
DIVERGIN
Continue For Feedback and Periodic Review and Revision
1. Identify progra to be reviewed with a view towards improvin Environmental Science studies content
2. Gather Informatio
3. Describe Program & Situation Surrounding Program
4. Define Transformations Which Might Improve Situation
5. Develop Models, Statement of Improved Situations
5a. Identify & use Other Inquiry Methods
5b. Select Models
6. Compare Models with Real Situations
7. Debate Desireable and Feasible Change
8. Implement
CONVERGING
ASSIMILATIN

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Table 1. College of Agriculture Enrollment in NASULGC Institutions by Degree Level, Fall 1986 - 1987

Program Area and Level	1986		1987		Percent Change (%)
	Reported[1] (n=69)	Estimated Total[2]	Reported[1] (n=66)	Estimated Total[2]	
Ag Sciences					
Two Year	3,993	4,006	3,599	3,635	-9
Baccalaureate	60,039	60,622	55,812	57,143	-6
Freshmen	12,901	13,062	11,969	12,254	-6
Sophomore	11,921	12,038	11,107	11,372	-5
Junior	15,102	15,239	14,143	14,480	-5
Senior	18,509	18,670	17,344	17,758	-5
Other	1,606	1,613	1,249	1,279	-21
Masters	11,440	11,570	10,861	11,127	-4
Doctoral	8,463	8,465	9,209	9,268	+9
Other Programs					
Two Year	149	149	922	922	**
Baccalaureate	8,142	8,263	8,559	8,869	+7
Freshmen	2,133	2,178	2,331	2,415	+11
Sophomore	1,570	1,599	1,789	1,854	+16
Junior	1,929	1,953	1,989	2,062	-1
Senior	2,291	2,323	2,248	2,329	0
Other	219	220	202	209	-5
Masters	584	584	499	524	-10
Doctoral	38	38	57	57	+50
Total					
Two Year	4,142	4,155	4,521	4,557	+10
Baccalaureate	68,181	68,885	64,371	66,012	-4
Freshmen	15,034	15,240	14,330	14,669	-4
Sophomore	13,491	13,637	12,896	13,226	-3
Junior	17,031	17,192	16,132	16,542	-4
Senior	20,800	20,993	19,592	20,087	-4
Other	1,825	1,833	1,451	1,488	-19
Masters	12,024	12,154	11,360	11,651	-4
Doctoral	8,501	8,503	9,266	9,325	+10

Source: Adapted from FAEIS, 1988a.

Reported figures show enrollments from responding colleges only.

Estimated figures show enrollments adjusted for nonrespondents.

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Table 2

Enrollment[1] in Colleges of Agriculture Classified by Degree Area, specialization, and Level as Reported by NASULGC Institutions, Fall 1987

(FAEIS, 1988 a)

Degree Area and Major Specialization	Enrollment in Agricultural Sciences and Other Programs by Degree Level				
	2 Year	B.S.	M.S.	Ph.D.	Totals
General Agriculture					
Agric. sciences, gen	350	3,160	219	10	3,739
SUBTOTAL	350	3,160	219	10	3,739
Animal Sciences					
Animal sciences, gen	396	8,745	833	412	10,386
An. breeding & genetics	0	118	66	166	350
Animal health	232	105	66	104	507
Animal nutrition	0	8	137	170	315
Animal physiology	0	146	149	157	452
Dairy production	119	513	103	78	813
Livestock	228	210	38	22	498
Poultry science	0	334	99	72	505
Pre-veterinary medicine	114	2,514	0	0	2,628
Veterinary science	57	149	42	17	265
Embryology	0	0	2	2	4
Endocrinology	0	274	11	1	286
Animal pathology	0	4	6	4	14
Animal pharmacology	0	0	12	32	44
SUBTOTAL	1,146	13,120	1,564	1,237	17,067
Plant Sciences					
Plant sciences, general	37	800	345	335	1,517
Agronomy	157	1,482	626	567	2,832
Horticulture science	396	2,037	423	339	3,195
Ornamental horticulture	243	758	79	41	1,121
Plant breeding & genetics	0	229	190	290	709
Plant pathology	0	46	295	366	707

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[1] Enrollment figures are those reported from 66 colleges. Figures have not been adjusted for nonrespondents due to difficulties in obtaining estimates for each specialization.

Table 2 (continued)

Enrollment in Colleges of Agriculture Classified by Degree Area, specialization, and Level as Reported by NASULGC Institutions, Fall 1987

Degree Area and Major Specialization	Enrollment in Agricultural Sciences and Other Programs by Degree Level				
	2 Year	B.S.	M.S.	Ph.D.	Totals
Plant physiology	0	4	91	179	274
Plant protection (IPM)	7	92	72	63	234
Turf management sciences	308	120	15	12	455
Landscape architecture	110	1,524	198	6	1,838
SUBTOTAL	1,258	7,092	2,334	2,198	12,882
Soil Sciences					
Soil sciences, general	4	266	248	255	773
Soil chemistry	0	0	8	26	34
Soil conservation	0	12	12	13	37
Soil mgmt & fertility	0	9	33	46	88
Soil microbiology	0	0	6	12	18
Soil physics	0	0	6	20	26
SUBTOTAL	4	287	313	372	976
gricultural Business & Mgmt					
Agric. bus. & mgmt, gen	286	1,476	108	7	1,877
Agric. business	41	2,111	21	20	2,193
Agric. economics	0	5,241	1,134	817	7,192
Farm & ranch mgmt	12	243	11	8	274
Animal pharmacology	0	0	12	32	44
SUBTOTAL	339	9,071	1,274	852	11,536
ducation, Comm, Social Sci.					
International agric., gen.	0	94	43	4	141
Rural sociology, gen.	0	272	137	143	552
Ag Communication/journalism	2	895	140	4	1,041
Extension education	0	197	204	36	437

Table 2 (continued)

Enrollment in Colleges of Agriculture Classified by Degree Area, specialization, and Level as Reported by NASULGC Institutions, Fall 1987

Degree Area and Major Specialization	Enrollment in Agricultural Sciences and Other Programs by Degree Level				
	2 Year	B.S.	M.S.	Ph.D.	Totals
Agricultural education	3	1,832	414	200	2,461
SUBTOTAL	5	3,290	938	387	4,620
Natural Resources					
Fisheries science	0	478	195	104	777
Range management	0	288	80	58	426
Renew. nat. resc., gen	0	653	131	63	847
Conservation & regulation	52	635	32	14	733
Resc protection & regulation	0	120	0	1	121
Forestry & related sciences	68	1,325	234	144	1,771
Forest biology	0	2	29	22	53
Forest engineering	0	2	0	0	2
Forest hydrology	0	0	1	0	1
Forest mensuration	0	430	56	15	501
Urban forestry	62	1	0	0	25
Wood sci., tech & industry	0	71	28	23	122
Wildlife management	48	1,699	337	151	2,235
Parks & recreation mgmt	5	805	71	47	928
Water resources	0	76	84	24	184
SUBTOTAL	235	6,585	1,293	676	8,789
Ag Engineering/Mechanization					
Agricultural mechanics	32	56	18	23	129
Agricultural mechanization	78	932	34	12	1,056
Agricultural eng sci	0	1,189	335	301	1,825
Animal pharmacology	0	0	12	32	44
SUBTOTAL	110	2,177	387	336	3,010

Table 2 (continued)

Enrollment in Colleges of Agriculture Classified by Degree Area, specialization, and Level as Reported by NASULGC Institutions, Fall 1987

Degree Area and Major Specialization	Enrollment in Agricultural Sciences and Other Programs by Degree Level 2 Year	B.S.	M.S.	Ph.D.	Totals
ood Sci/Human Nutrition					
Food sciences, general	0	2,219	821	542	3,582
Dairy processing	0	80	9	8	97
Food distribution	22	126	0	0	148
Food engineering	0	39	28	19	86
Food packaging	0	538	30	0	568
Food technology	104	208	108	67	487
Nutritional sciences	26	1,230	264	233	1,753
SUBTOTAL	152	4,440	1,260	869	6,721
elated Biol/Phys Sci					
Biology, general	0	3,458	371	679	4,508
Biochem & biophysics	0	1,812	155	559	2,526
Botany	0	79	103	119	301
Microbiology/cell sci	0	806	182	368	1,356
Biometrics/biostatistics	0	66	25	35	126
Parasitology	0	0	4	0	4
Entomology	0	237	402	491	1,130
Climatology/meteorology	0	132	37	21	190
SUBTOTAL	0	6,590	1,279	2,272	10,141
ther (Non-Agric.) programs					
Home economics, general	411	6,192	332	27	6,962
Other programs	511	2,367	167	30	3,075
SUBTOTAL	922	8,559	499	57	10,037

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Table 2 (continued)

Enrollment in Colleges of Agriculture Classified by Degree Area, specialization, and Level as Reported by NASULGC Institutions, Fall 1987

Degree Area and Major Specialization	Enrollment in Agricultural Sciences and Other Programs by Degree Level				
	2 Year	B.S.	M.S.	Ph.D.	Totals
All Ag Specializations					
TOTAL	3,599	55,812	10,861	9,209	79,481
All Specializations					
TOTAL	4,521	64,371	11,360	9,266	89,518

TABLE 3. ENVIRONMENTAL AWARENESS COURSES OFFERED AT SOME AGRICULTURE AND NATURAL RESOURCES COLLEGES

o Social and Ecological Aspects of Modern Agriculture

o Human Response to Chemicals in the Environment

o Environmental Issues in the United States

o Economic Growth: Man and His Environment

o Elements of Environmental Pollution

o Conservation of Natural Resources

o Health and Environment in America

o Population, Resources, and Environment

o Cultural and Environmental Systems

o Politics of Environmental Issues

o Environmental Studies, the Social Perspective

o Environmental Studies, the Humanistic Perspective

o Social and Ecological Aspects of Health and Disease

o Energy and Society

o Urban Society and Environment

o Social and Ecological Changes in America

o Conservation Ecology

o Principles of Environmental Science

o Environmental Aesthetics

o Environmental Decision Making

o Environmental Ethics

o Environmental Analysis

o The Global Ecosystem

TABLE 4. ENVIRONMENTAL CAREER BACCALAUREATE PROGRAMS OFFERED IN SOME AGRICULTURE AND NATURAL RESOURCES COLLEGES

Resource Management

Earth and Atmospheric Sciences - Meteorology, Soils, Physical Oceanography, Geography
Environmental and Natural Resource Economics

Environmental Planning and Design

Landscape Architecture

Environmental Chemistry

Environmental and Occupational Health Science

Environmental Sanitarians

Environmental Teacher Education

Pollution and Treatment Sciences

Marine Studies

Radiation - Nuclear Studies

Water Resources

Human Ecology - Public Policy, Population, Social Impact

International Environmental Studies

Environmental Communications

Fisheries Science

Forestry

Wildlife Science

Integrated Pest Management

Environmental Engineering

PreLaw - Environmental Emphasis

Ecology

Environmental Policy Analysis and Planning

Environmental Horticulture

Range Management

Resource Protection and Regulation

Conservation

Parks and Recreation

Table 5. Short Courses and Continuing Professional Education Programs, Cook College, Rutgers University, 1988-1989.

BIOLOGICAL AND AGRICULTURAL ENGINEERING

Stormwater Management for Engineers

Microcomputer-Aided Erosion Control, Hydrology and Hydraulics

Sediment and Erosion Control: Planning, Design & Applications

ENVIRONMENTAL RESOURCES

Geology and Hydrology of the New Jersey Valley and Ridge, Highlands and Lowland Provinces

Geology and Hydrogeology of the Coastal Plain

Groundwater Resource Management

Water Treatment Systems

Park Management

Stream Encroachment

Basic Hydrology

ENVIRONMENTAL SCIENCE

Radon: Fact, Fiction, and the Future

Wastewater Pumping Station Design

Operation & Maintenance of Wastewater and Treatment Plants

Flow Meters: Fundamentals and Operation

Operation & Maintenance of Wastewater Collection Systems

Operation & Maintenance of Water Distribution Systems; Installation & Maintenance of Fire Hydrants

Operation & Maintenance of Water Treatment Plants

Health Effects of Contaminants in Drinking Water

Municipal Recycling

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Table 5 (continued). Short Courses and Continuing Professional Education Programs, Cook College, Rutgers University, 1988-1989.

ENVIRONMENTAL SCIENCE, CONTINUED

Safe Drinking Water Act

Sanitary Surveys and Standards for Public Water Operations

Regulation & Inspection of Public Bathing Places

Ultimate Disposal of Liquids (Effluents) Organic and Inorganic Sludges

Advanced Topics in Activated Sludge:

Troubleshooting Process Problems

Environmental Modeling: Fundamental and New Concepts

Leaf Composting Conference

LANDSCAPE ARCHITECTURE

Pesticide Safety for Landscape Contractors

Salt and Air Stresses on Landscape Plants

RADIATION SCIENCE

Basic Radioisotope Theory

Radioisotope Laboratory Safety

Biological Effects of Ionizing Radiation

Radiation Protection Program Management

Standards and Regulations for Radiation Protection

Environmental Assessment and Survey Techniques

SOILS

Soils and Site Evaluation

Identifying N.J.'s Wetlands

Wetland Systems

Coastal Zone Management

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APPENDIX 1. CERTIFICATE PROGRAM IN ENVIRONMENTAL STUDIES
COOK COLLEGE, RUTGERS UNIVERSITY

*Social Strategies for Environmental Protection Certificate (24 credits)

Solving environmental problems often requires social intervention skills and not just an understanding of the biophysical environment. This certificate program is designed to give students, regardless of their major, an understanding of individual behavior, social organization and values, politics, law, and communication as these fields relate to environmental intervention. The aim is to provide action-oriented training in skills that strengthen environmental protection efforts. The program culminates in a practicum experience in which these skills are applied to an environmental issue of current concern.

Required Courses (15):

- Environmental Law (3 credits)
- Legal Foundations of Urban Planning (3)

    or

- Politics of Environmental Issues (3)
- Behavior and Environmental Quality (3)
- Practicum in Environmental Protection (3)
- Environmental Ideology and Media (3)

Electives (9):

- Environmental Management (3)
- Environmental Law (3)

    or

- Legal Aspects of Conservation (3)
- Energy Resource Management (3)
- Topics in Environmental Control and Public Policy (3)
- Environmental Economics (3)
- Research Methods in Human Ecology (3)
- Environmental Policy Process (3)
- Popular Writing on Technical Topics (3)
- Environmental Psychology (3)
- Social Action Strategies and Techniques (3)
- Environmental Sociology (3)
- Municipal Implementation of Planning Programs (3)

    or

- New Jersey Planning Practice (3)
- Social Aspects of Environmental Design (3)

APPENDIX 2. - The National Agriculture and Natural Resources Curriculum Project (Additional Details), March 1989

STATUS OF THE PROJECT

The course areas which have been developed and are being disseminated through workshops and curriculum/course materials are: a) Systems Approaches to Food, Agriculture and Natural Resource Problems; and b) Ethical Aspects of Food, Agricultural, and Natural Resource Policy. About 500 people have participated in training workshops on new approaches, concepts, and materials developed by two different teams. The materials developed are appropriate for new courses or modules at the undergraduate and graduate levels. They also form the basis for analyzing and suggesting strategies for curriculum change.

A. SYSTEMS APPROACHES TO FOOD, AGRICULTURE AND NATURAL RESOURCES PROBLEMS

A 7-member faculty team coordinated by Dr. Kathleen Wilson of the University of Hawaii prepared the workbook, case studies, syllabi, teachers' guide, three computer software packages, and other teaching materials.

1. SYSTEM TEAM:

Richard H. Bawden - Hawksbury Agricultural College, Australia
Lovell Jarvis - University of California, Davis
George E.B. Morren - Rutgers, The State University of New Jersey
Mark E. Singley - Rutgers, The State University of New Jersey
Robert S. Sowell - North Carolina State University
Donald Vietor - Texas A & M University
Kathleen Wilson - University of Hawaii, Honolulu

2. BOOKS:

Two books will be published by Macmillan Publishing Company in early 1990: Systems Approaches for Improvement in Agriculture and Resource Management, by Kathleen Wilson and George E.B. Morren, Jr. with Richard Bawden, Donald S. Vietor, Mark Singley, and Robert Sowell. A companion book for professionals and educators has been written by Richard Bawden.

3. TRAINING WORKSHOPS

Members of the team and others also designed and conducted intensive training workshops:

Title	Dates	Location	Participants
1st Faculty Workshop	May 26-June 6, 1986	Colorado State Ft. Collins, CO	42 faculty from 29 colleges and universities, representing 15 different academic disciplines
1st Administrators Workshop	June 9-11 1986	Colorado State University Fort Collins, CO	29 deans, department heads & other administrators
Graduate Level Curriculum Building Workshop for Administrators	August 6-13 1986	Rutgers Univ. New Brunswick, New Jersey	6 deans and department heads from 3 Dominican

and Government Planning officials from the Dominican Republic			Republic Universities and a representative of the government planning office
2nd Faculty Workshop	May 24-29 1987	North Carolina State University	25 faculty from 17 colleges in the U.S. and 1 in Italy representing 19 different academic disciplines
FAO Symposium	June 8-10, 1987	Rome, Italy	40 officials from FAO
Western Region Agricul. Systems Workshop	Nov 1-4, 1987	Asilomar, CA	26 faculty from 10 colleges
Workshop on Systems Approaches to Teaching, American Society of Agronomy	Nov 28-29, 1987	Atlanta, GA	59 agronomists
Symposia on Systems Perspectives, American Society of Agronomy	Nov 30, 1987	Atlanta, GA	150 agronomists
Inland Pacific Northwest Systems Workshop for Agriculture and Home Economics	August 10-13 1988	Post Falls, Idaho	47 faculty and administrators from western universities
Systems Workshop for the Social Sciences, Southern Illinois University	Sept 19-23 1988	St. Louis, Missouri	30 faculty from S.I.U.
International Conference on Agricultural Higher Education (Systems)	Oct. 1-8 1988	Restin, Virginia	106 participants (49, foreign agric. univ; 29, USAID; 19 U.S. univ; 9 other organiz.)
South Dakota	March, 1989	Brookings, South Dakota	21 faculty

FUTURE PLANS. Three USAID cosponsored International Workshops are being considered.

B. ETHICAL ASPECTS OF FOOD, AGRICULTURE AND NATURAL RESOURCE POLICY

A 13-member faculty/business team coordinated by Dr. Robert Matthews of Rutgers and Dr. Thomas Ruehr of Cal. Poly, San Luis Obispo developed curriculum and workshop materials on ethical aspects of food, agriculture, and natural resource policy.

1. ETHICS TEAM

Jeffrey Burkhardt - University of Florida
Lawrence Busch - University of Florida
Stanley E. Curtis - University of Illinois-Urbana
Glenn L. Johnson - Michigan State University
Harry O. Kunkel - Texas A & M University
J. Patrick Madden - Pennsylvania State University
Robert Matthews - Rutgers, The State University of NJ
Robert E. McDowell, Jr. - North Carolina State Univ.
Roy E. Morse - RJR/Nabisco
Thomas A. Ruehr - Cal Poly State Univ., San Luis Obispo
Mark Sagoff - University of Maryland
Paul Thompson - Texas A & M University
Eileen Olson Van Ravenswaay - Michigan State University

2. TRAINING WORKSHOPS

The first training workshops for faculty and administrators with course and curriculum materials were conducted June 14-26, 1987 at the University of Kentucky. Details are as follows:

Title	Dates	Location	Participants
1st Faculty Workshop	June 14-26, 1987	University of Kentucky, Lexington	28 faculty and 1 consulting firm official from 21 colleges and universities representing 15 academic discipline program areas
1st Administrators Workshop	June 23-26 1987	University of Kentucky, Lexington	22 administrators from colleges and universities, NSF and the Journal of Agriculture and Human Values representing 19 organizations

3. BOOK. Plans are underway to publish the workshop materials as a text, by Matthews, Thompson and Van Ravenswaay, with a due date of fall 1990.

F.